POWER PLANT ENGINEERING

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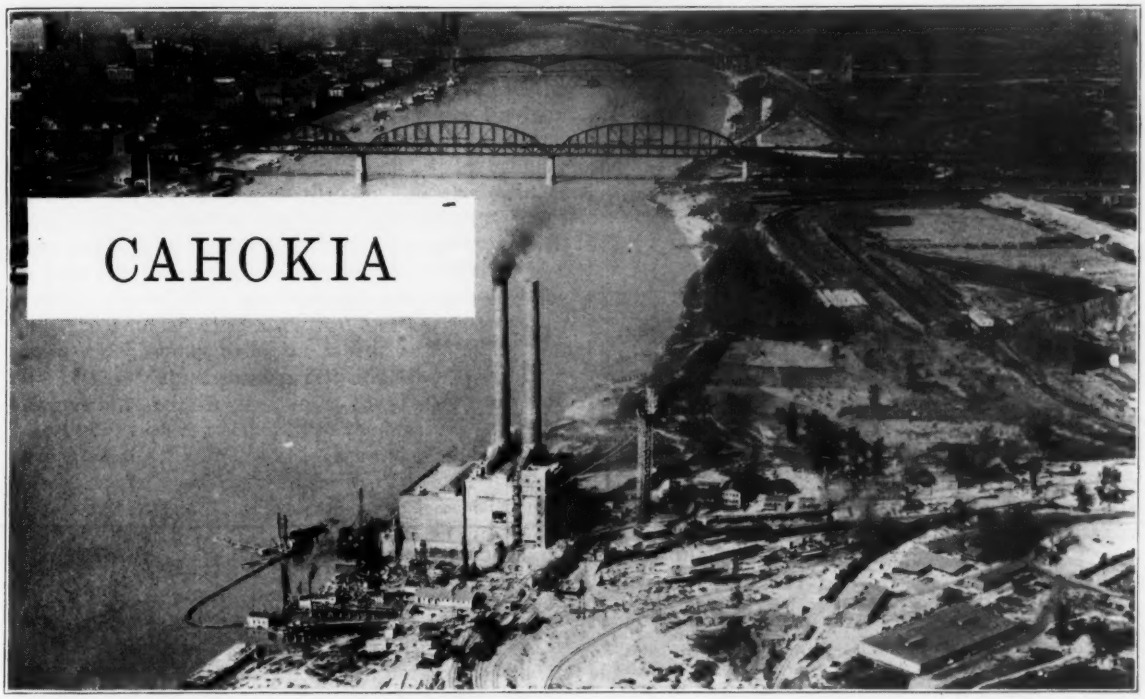

CAHOKIA IS THE FIRST LARGE STATION WITH THE PULVERIZED FUEL EQUIPPED IN THE SAME BUILDING WITH THE BOILERS. IT HAS THE LARGEST ULTIMATE CAPACITY OF ANY PULVERIZED FUEL PLANT AND IS THE FIRST LARGE STATION WITH VERTICAL ISOLATED PHASE ARRANGEMENT AND WITH THE CIRCUIT BREAKER MECHANISM ON THE LOWEST INSTEAD OF ON THE HIGHEST FLOOR. CAHOKIA IS A SUPER POWER PLANT IN EVERY SENSE OF THE WORD AND IS AN EXCELLENT EXAMPLE OF MODERN ACHIEVEMENT

SITUATED WITHIN 20 miles of the border of Illinois' almost limitless coal fields, on the bank of the longest and mightiest river in North America and less than a mile from the business center of St. Louis, Mo., the Cahokia Station of the Union Electric Light and Power Co. of Illinois certainly could not have been built in a more desirable location. Apparently, the engineers were cognizant of this fact, for in designing the plant they did justice to the site and have produced a structure that is truly worthy of the name "Super Power Station."

With its stacks towering 355 ft. above the river bank and its lower level extending 44 ft. below the high water line, Cahokia is the biggest power development on the Mississippi River and one of the largest in the world. Heretofore, Keokuk has been the most important power project of interest to St. Louis but today Cahokia takes the lead. When completed, Cahokia will have four times the year round capacity of Keokuk.

Cahokia is located three-fourths of a mile south of the municipal bridge crossing the Mississippi River at St. Louis in Illinois. It takes its name from the pioneer village of 1716 that was the first seat of American government in Illinois.

When it became necessary for the engineers of the Union Electric Light and Power Co. of Illinois to select the site for a new power plant, Cahokia seemed to possess all of the natural advantages incident to the economical generation of power. It is only 20 mi. away from the coal fields of Illinois and for condensing water, it has the vast volume of the Mississippi River itself to draw upon. Furthermore, it is close to the point at which the electrical energy is used. Offhand it might appear that the station would have been more favorably located had it been built on the Missouri side of the river, since this is the side on which most of the power is used. This, however, would have necessitated the bringing of coal across the river involving heavy freight charges, which are now eliminated.

General Features

Cahokia Station will have an ultimate capacity of 300,000 kw. and will be composed of four sections each containing two generating units. Each section will have condensing water intakes inside of the building and each section is independent of the others except for the discharge tunnel, raw coal delivery and emergency station power. This arrangement permits of future installations taking advantage of new developments in the art.

rests on cast-in-place concrete piles from 20 to 35 ft. long. The entire substructure is water proofed up to grade 37 ft. by means of fabric and asphalt membrane waterproofing.

For fuel, the station uses principally Illinois bituminous coal of about 10,000 B.t.u. heat value. This coal is pulverized and burned under cross-drum boilers in deep furnaces of large volume. The boilers are of 1800 hp. capacity, 20 tubes high with 580 sq. ft. of tube surface in a water screen at the bottom and lower rear wall of the

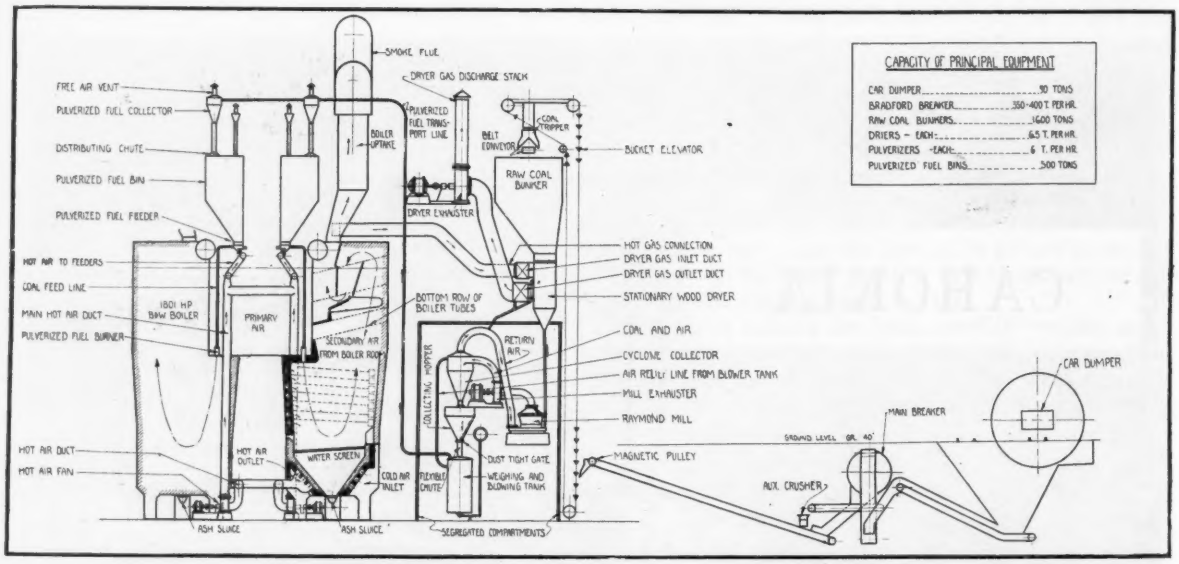

FIG. 1. DIAGRAM SHOWING TRAVEL OF COAL THROUGH CAHOKIA

The site covers 52 acres with an average elevation of 14 ft. below record high water. Provision is made for a 43 ft. variation in water level. The west portion of the building comprises the turbine room, electrical and river bays extending to the "inner harbor line" and supported on concrete piles in the river bed. The boiler room is alongside forming the east portion of the structure. Levees and cofferdams were constructed on the north, south and west sides of the site to elevations above high water. These connect with the government levee on the east and carry permanent tracks and roadways. At the present time, the first section of 60,000 kw. is carrying load and the second section is under construction. The building, containing boiler room, turbine room, electrical and river bays is 221 ft. wide, 104 ft. high above new ground level and at present is 173 ft. long. The ultimate length will be 650 ft.

At present the station contains 57.3 cu. ft. of volume per kilowatt installed, but when the ultimate station is completed this ratio will reduce to 43.3 cu. ft. per kw. This, of course, is due principally to the fact that later units will be of larger capacity and that certain equipment in the present plant has been installed large enough to take care of subsequent units.

Buildings are constructed with brick curtain walls on steel frames and with reinforced concrete floors throughout. They are supported on concrete piles driven through silt, sand and clay into hard gravel strata. The piles under the river and electrical bays and the turbine room were precast and range from 45 to 75 ft. in length. They were driven with water jets at 250-lb. pressure. The boiler room

furnaces. Superheaters are located above the sixth row of tubes in the boiler. No economizers are used. Stacks 325 ft. high above the burner arches furnish natural draft for combustion.

The steam boilers are designed for 350 lb. and steam is delivered to the throttle at 300 lb. and a total temperature of 690 deg. Each 30,000 kw. generating unit has one surface condenser with two circulating pumps having individual capacity of 33,000 gal. and combined capacity of 54,000 g.p.m. One elliptical condenser pit contains both of the two main condensers for one section.

Main generators are all located in one row end to end with the steam ends together on a narrow platform near the center of the room open to light and air from the roof to the bottom of the condenser pit.

Station auxiliaries are normally motor driven from house transformers and when advisable, from house turbines with saturated core reactors to prevent overloading of these house turbines.

Main bus includes one section for each main generator sectionalized through by reactors and all equipment of each phase in a separate room, one phase above the other. The single-phase oil circuit breakers are coupled together and actuated by motor mechanism located on the floor beneath the vertically arranged phase chambers. The reserve bus bars are similarly isolated but include two main generators on each bus section.

In describing the details of this station perhaps the most logical point to commence is at the coal handling system. By following the path of the coal through the plant

and later, the steam from its point of generation to the final conversion of its heat energy into electrical energy, we shall have a clear mental picture of the operating features as well as of the construction of the plant.

Coal Handling and Pulverizing

Coal from railroad cars is unloaded into a large receiving hopper by means of a 90-T rotary car dumper. This dumper will completely empty a 50-T car of coal in a trifle over one minute with only one unskilled operator in charge. This is the first car dumper of this particular type ever constructed and has a number of interesting features an account of which will be found on page 197 of the Feb. 1 issue of Power Plant Engineering.

From the receiving hopper the coal is carried to a 12 by 17-ft. Bradford coal breaker having a capacity of 350 to 400 T. per hr. This breaker is nothing more nor less than a huge hollow cylinder rotating about a horizontal axis slightly inclined. The interior wall of the cylinder is fitted with projections or shelves. As the cylinder rotates, coal is carried to the top of the cylinder on the shelves and falls to the bottom where it breaks by impact. This procedure is continued until the coal is reduced to a size sufficiently small to pass through perforations in the sides of the cylinder. Unbroken coal together with foreign material which cannot be broken is discharged at the end of the breaker onto a picking belt and is delivered to a swing ring crusher. In other words, the crusher takes only the material which is rejected from the breaker.

After passing the Bradford breaker and crusher the coal is carried over magnetic separators where any foreign iron or steel is removed and is delivered to the buckets of a Link-Belt bucket elevator for further delivery to the upper part of the boiler house. Here it is dumped on a distributing belt which runs the entire length of the building immediately above the raw coal bunkers. A traveling tripper distributes the coal evenly in the raw coal bunkers. It is in these raw coal bunkers that the coal is stored preparatory to its being pulverized.

Method of Pulverizing

Before the raw coal is delivered to the pulverizers it is necessary that it be dried. If moist coal, that is, coal with over 5 or 6 per cent moisture is delivered to the pulverizers, the output will be diminished, so it is dried in stationary driers. These driers each have a capacity of 6½ T. per hr.

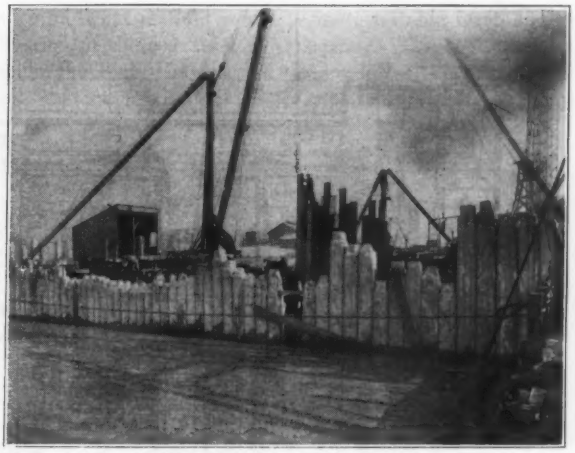

FIG. 2. A CLOSE-UP VIEW OF THE CONCRETE PILING UPON WHICH THE STATION STANDS

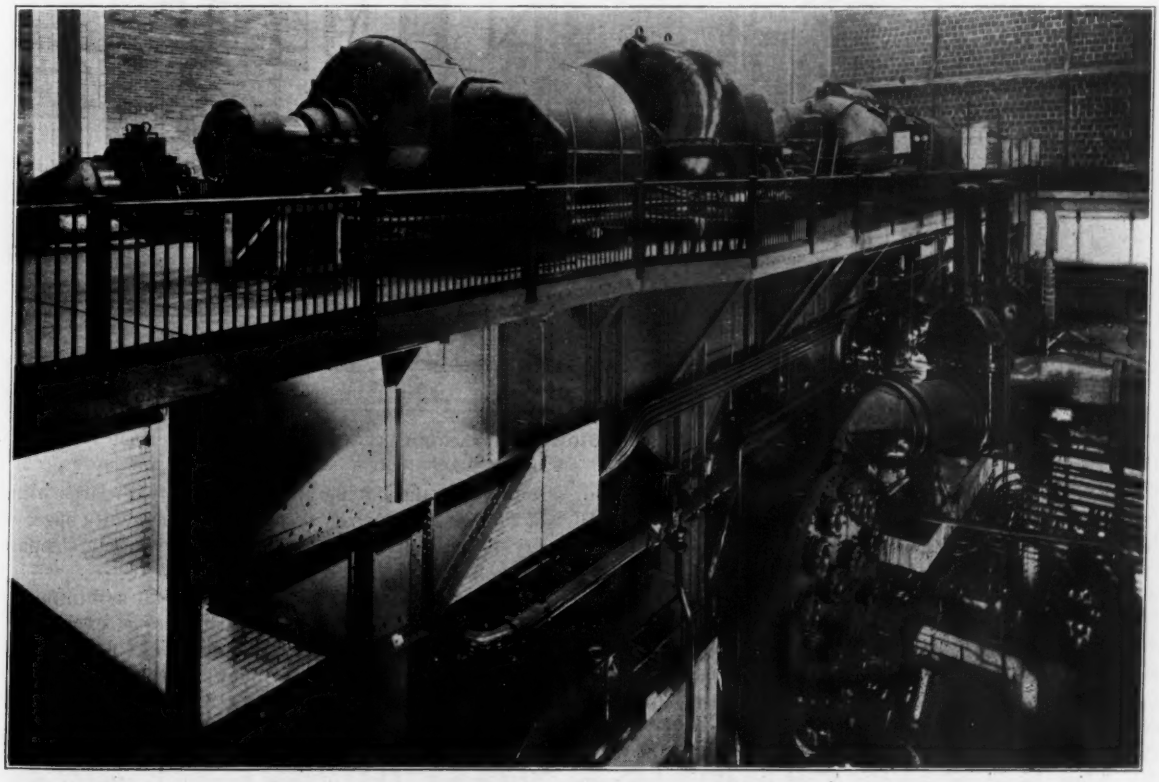

FIG. 3. THE TURBINES AND THE CONDENSER PIT

and reduce the moisture from 12 to 5 per cent. Their operation will be evident from the flow diagram of the coal system shown in Fig. 1. Flue gas is drawn from the breeching at a point directly above the boilers into the drier, where it comes in direct contact with the raw coal. The coal passes through the drier in the same direction as the gas. The gases are drawn out of the drier at the bottom and are exhausted to a separate gas discharge stack by means of 60,000-c.f.m. Sturtevant fans. In this way, all excess moisture is removed from the coal and reduced to the proper condition for pulverizing.

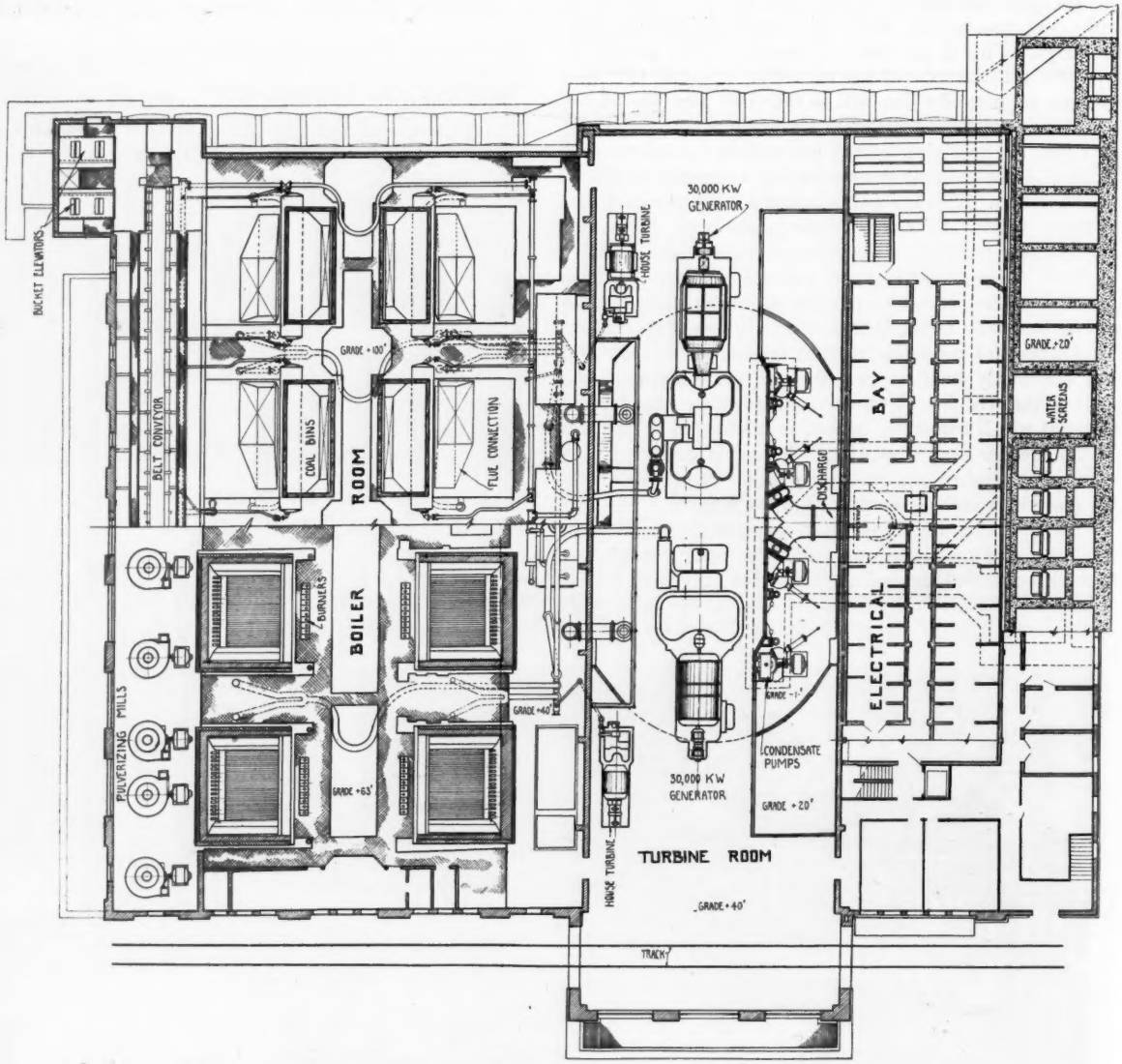

FIG. 4. A PLAN OF THE STATION SHOWING ARRANGEMENT AT VARIOUS LEVELS

As may be noted from the flow diagram, the next step in the process is the actual pulverizing. This is accomplished by means of six roll impact type pulverizers. The powdered coal is removed from the pulverizing mills by a motor-driven fan and blower into a cyclone collector which discharges into a conical collecting hopper fitted at the bottom with a dust tight gate.

When the desired quantity of pulverized fuel has accumulated in these collecting hoppers, an operator opens the gate at the bottom of the hopper and the coal flows by gravity into the weighing and blowing tank immediately below. These tanks are permanently mounted on scales so that before each charge is delivered to the bunkers it is carefully weighed. The entire drying and pulverizing equipment is installed in a narrow section of the building completely isolated from the boiler room by a heavy masonry wall, and having an outside wall with large windows of thin glass. One row of panes is permanently open. The drying and pulverizing sections are furthermore separated from each other by a concrete floor.

This type of construction reduces to a minimum the danger caused by the remote contingency of explosion. All possible precautions are taken to prevent dust explosions but if one does occur, the windows in the outside wall will offer practically no resistance and the destruction will be reduced to a minimum.

Nine pulverizing mills are installed, that is for the first section. Eight of these are of 6 T. capacity each and one is of 15 T. capacity. Eight of the 6-T. mills are neces-

sary for the eight boilers and when operated 16 hr. a day produce all the coal needed for 24 hr. operation of the plant.

From the weighing tanks, the powdered fuel is blown by compressed air through 4-in. pipes, a total distance of 160 ft. vertically, to 70-T. pulverized coal bins above and in front of each boiler. The air transport system is equipped with cyclone separators above the coal bins for the separation of air and coal.

Each weighing tank is provided with a 4-in. line to a separate bin but if necessity demands, coal may be distributed from any tank to any coal bin by means of a connecting system of lines. In other words, while under normal conditions each pulverizing mill together with weighing tank and coal bin is a complete unit, provision is made for these nozzles in a thin stream and ignites almost instantly in the intense heat of the furnace.

Furnaces

One striking feature in the design of the furnace lies in the large combustion space provided. This is considered necessary because of the long flame coal used. Before the final plans for the design of the station were decided upon, McClellan and Junkersfeld, Inc., the engineers and constructors, conducted an exhaustive series of tests to determine what method would be most suitable for the combustion of the coal used at this plant. The coal available from the Belleville district has a relatively low heat content and runs as high as 17 per cent ash. The fusing point of the coal is about 2000 deg. F.

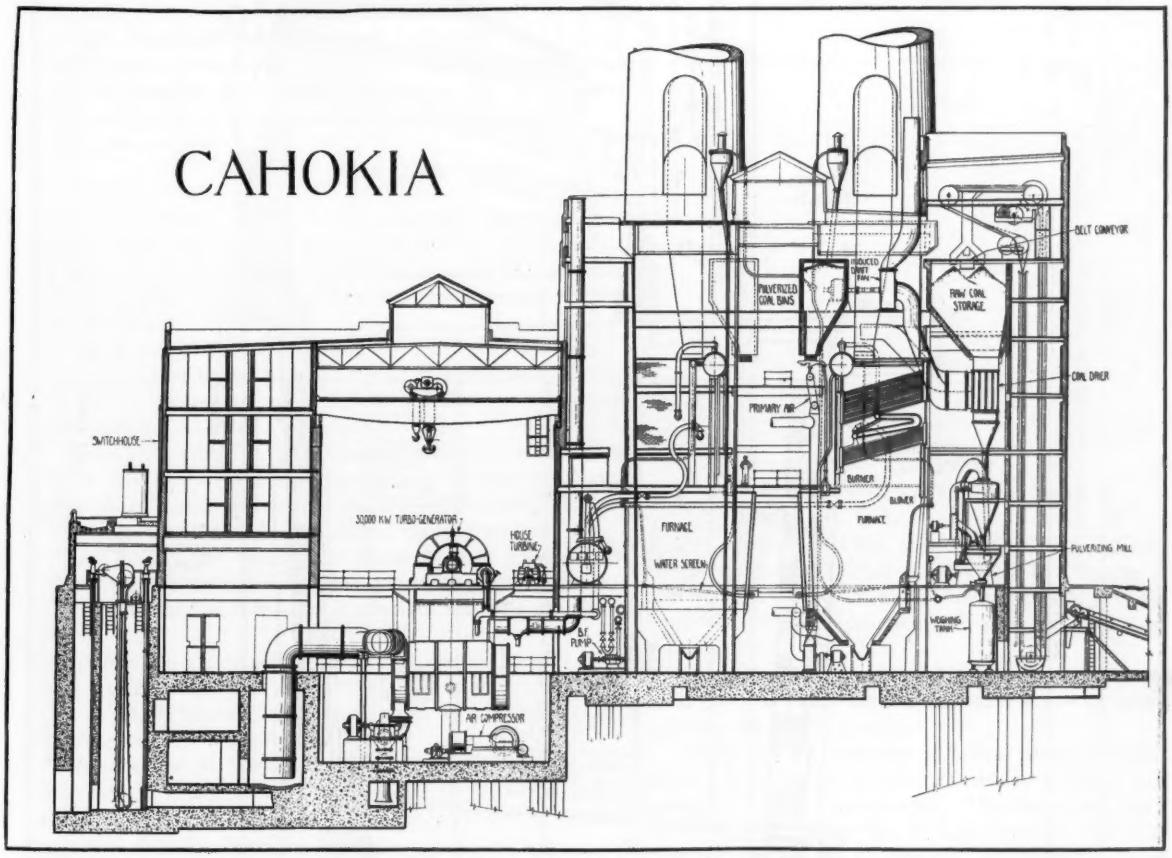

FIG. 5. CROSS SECTION THROUGH CAHOKIA

feeding any coal bin in the boiler room of any one section from any pulverizing unit. This arrangement imparts the flexibility necessary in case of emergency.

Next, the coal travels by gravity from the bins to the group drive feeders and is blown into the furnace through inclined vertical burners. Just previous to its entrance into the furnace, that is, at the feeders, the coal is mixed with primary air. The path of the primary air may be traced on the flow diagram. It is drawn in between the hollow furnace walls at the extreme lower part of the furnace or rather, the ash pit, and after being heated, is forced by a blower into the fuel feeding device as described above.

Each boiler is fitted with 10 burners. These are fan shaped devices fitted with a number of nozzles at the bottom. The fuel mixed with the primary air emerges from

Results obtained in the experimental studies indicated that this coal could be used most economically in the pulverized form, and this method was therefore adopted. The furnace volume is 11,440 cu. ft. per boiler.

Furnaces are built with air-cooled side walls and ash hoppers, the latter serving as heaters for the primary air and the former as heaters for the secondary air. About 85 per cent of the total air required for combustion passes through the hollow walls. The primary air fans are four in number and are installed in the basement as shown in Fig. 5. These fans are Sturtevant fans of 200,000 c.f.m., 15-in. static pressure capacity and are driven by 100-hp., 2300-v. induction motors.

Each furnace is fitted with a water screen at the bottom and back of the furnace. These water screens con-

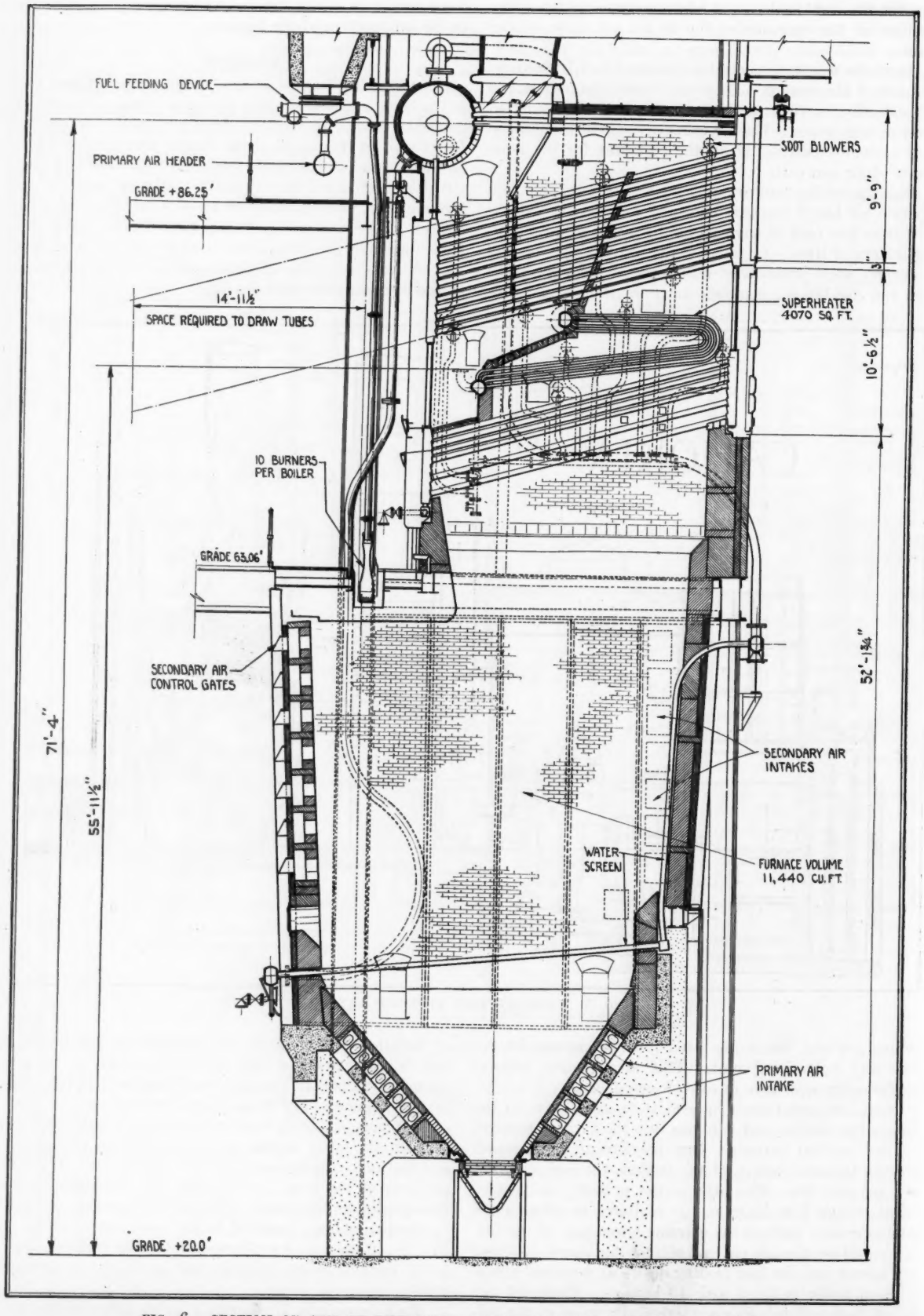

FIG. 6. SECTION OF ONE OF THE BOILERS SHOWING LARGE FURNACE VOLUME

tinued in the lower part of the back furnace wall. The purpose of this screen is to cool the molten ash to prevent it from damaging the refractories and to keep it from passing upward through the boiler. The solidified ash falls through the water screen into the ash pit below where it is sluiced off periodically.

As all the heat that is abstracted from the furnace by the water screen is delivered to the boiler in the heated water, there is no loss involved in the process. In this connection, it is of interest to note that economizers are not installed in this station. According to the engineers, the present fuel conditions at this plant do not warrant the use of economizers although provision has been made so that they can be installed at a later date if the price of the fuel should then justify the expense.

For handling the ashes two 6-in. manganese steel lined centrifugal dredge pumps are installed. Water sluicing troughs furnished by Allen-Sherman-Hoff Co. are located under each furnace and connect to a common discharge pipe discharging to a sump external to the boiler house from which ashes are pumped by the dredge pump.

Boiler Details

Eight 1801-hp., 350-lb. gage Babcock and Wilcox boilers are installed. These are horizontal, cross-drum sectional units with a total heating surface of 18,010 sq. ft. Units are 20 tubes high and 38 tubes wide. Drums are 60 in. in diameter, 33 ft. 6 in. long and are made of 1⅜ in. steel plate.

Each boiler has Babcock and Wilcox Alert type superheaters located above the sixth row of boiler tubes as shown in Fig. 6. These are made up of 2-in. tubes and have a total heating surface of 4070 sq. ft.

The 10 feeders for the pulverized coal with which each boiler unit is equipped are connected by clutches to a common drive shaft, driven by a 400—1200-r.p.m., 15-hp. Westinghouse totally enclosed direct-current motor.

All boilers are fitted with Diamond soot blowers, 18 elements to each boiler. Feed water regulators are the Copes made by the Northern Equipment Co., two units per boiler.

Baffling is arranged for three pass operation with natural draft. Four boilers are connected to each chimney; two breeching connections to each chimney with two boiler uptakes to each breeching.

Stacks are of tile-concrete construction built by the Wiederholdt Construction Co. They are 19 ft. inside diameter at the top, are 325 ft. high and are supported on building steel directly above the boilers.

Boiler Room Arrangement

Figures 4 and 5 will serve to indicate the general arrangement of equipment in the boiler room. The boilers are arranged on both sides of the room with the firing aisle in the center. The pulverized coal storage bins are located in front and at the top of the boilers, but are so designed as not to obstruct natural illumination from the skylight above. The various operating levels are provided with gratings so that natural illumination is provided on even the lowest operating level.

The present boiler room is 171 ft. long and 106 ft. in width; the length of the ultimate boiler room will be 630 ft.

All boilers are fitted with a complete line of recording and indicating instruments, and the Bailey system of combustion control is at present installed on two of the boilers.

To notify the boiler watch engineer of anticipated load requirements, a Kilberscope system has been installed. This consists of an indicator in the main control room and one in the boiler house. Each indicator is calibrated to read in "Kilbers" (thousands of pounds of steam per hour) and there are with each indicator 24 General Electric Co.'s pilot lamps and 24 Western Electric jacks, each representing one-half hour intervals.

Feed Water

Feed water is delivered to the boilers by four 750-g.p.m., 425-lb. per sq. in. Allis Chalmers Mfg. Co. centrifugal pumps, one steam-driven by a 300 hp. Terry turbine and three electrically driven by 300-hp., 1500-1760-r.p.m.,

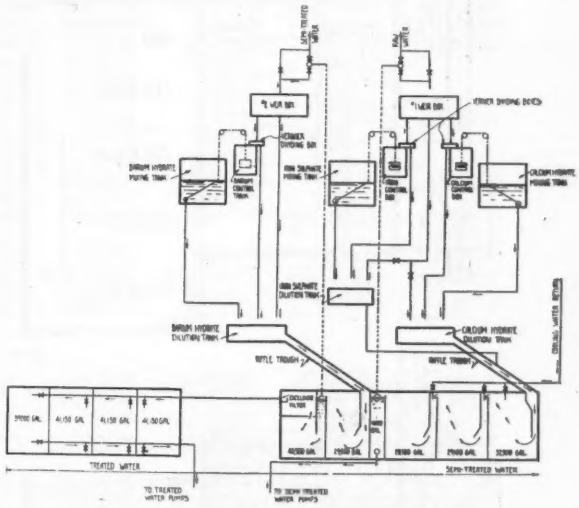

FIG. 7. THE WATER FLOW DIAGRAM

2300-v. General Electric induction motors. The speed of the motor-driven pumps is governed by Ruggles-Klingemann Mfg. Co. steam-water differential regulators. The steam-driven pump is governed by a Fisher excess pressure regulator.

Boiler feed water is heated in one closed heater on each main turbine using bled steam from a low pressure stage and in a deaerating heater.

Water for all purposes is taken from the Mississippi which contains more or less sediment in addition to a large amount of scale-forming salts. The water treating system at this station is therefore of large capacity, and is divided into two main parts, the primary and secondary treatment systems, respectively. The primary treated water is used for cooling bearings and general service requirements while the secondary treated water is used as evaporator feed water and for emergency makeup to the boilers.

In Fig. 7 is shown a flow diagram of the water treating system which was supplied by the Graver Corporation. Taking up the primary treatment first, it will be noted that raw water enters weir box No. 1 at a rate which is governed by the level of the water in the primary of semi-treated water storage tank. A float in the semi-treated water tank controls a chronometer valve in the main feed line to the treating system. In the weir box the water flows over a circular weir into two dividing boxes which control the amount of chemicals added to the water in exact proportion to the amount of raw water entering the system.

(Continued on page 397)

Power Plant Design and Operating Cost---I

Comparison of Costs Which Enter Into Power Plant Design and Maintenance When Various Types of Prime Movers Are Used

TO STUDY THE relative costs of installation of various types of prime movers in a power plant, involves first a consideration whether the plant is to run condensing or non-condensing and whether or not superheated steam will be used. A second consideration is the exact type of prime mover which is to be used. A study of this kind has recently been reported by the prime movers committee of the N. E. L. A., the basis of the study being the detailed costs of a 1500-kw. central station.

For the sake of a direct comparison the plant is assumed to be located in a small city near an adequate supply of water and with necessary railroad facilities. In all cases the building was assumed to be constructed of steel frame and brick wall, the construction costs being based on prices of material and labor in the vicinity of Philadelphia in February, 1923.

All plants were laid out with four 500 kw. generating units and ample boiler capacity to provide for carrying the peak load with one generator and one boiler out of service. All electric current is assumed to be generated at 2300 v., 3-phase and 60 cycles. The problems were worked out for load factors of 25, 50 and 75 per cent.

LABOR COST

Class of Employe	Steam engine plants load factor 25%	Steam engine plants load factor 50% and over	Oil engine plants load factor 25 and 50%	Oil engine plants load factor 75%	Salary for Month
Chief Engineer..	1	1	1	1	$225
Watch Engineer.	2	2	3	3	150
Asst. Engineer..	0	0	3	3	125
Fireman	3	3	0	0	125
Laborers	1	2	0	1	90

Classes of prime movers considered, are, steam turbines, uniflow engines, four-valve engines both simple and compound, Corliss engines both simple and compound and Diesel engines. The boiler plants have been laid out to operate at maximum efficiency at 175 per cent of normal rating. The boilers are all stoker fired and capable of operating at 250 per cent of normal rating for a period of 2 hr. Boiler efficiencies were assumed at 65 per cent for a load factor of 25 per cent, 70 per cent for a load factor of

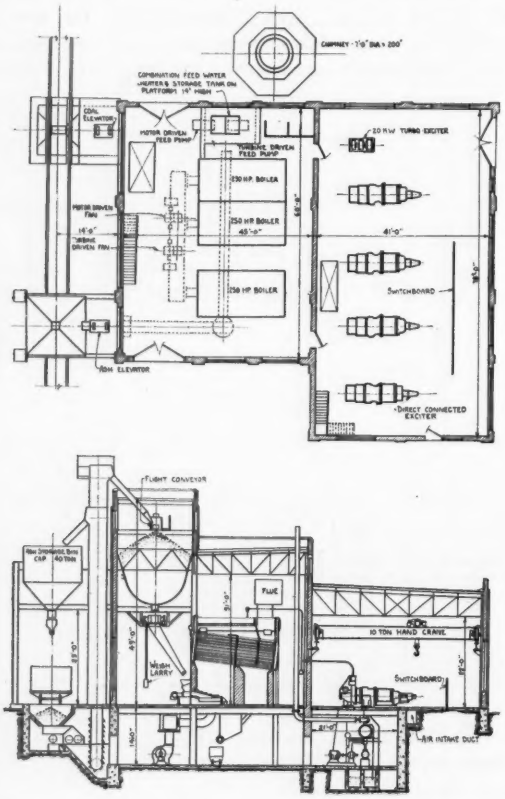

FIG. 4. PLAN AND ELEVATION OF THE CONDENSING TURBINE PLANT

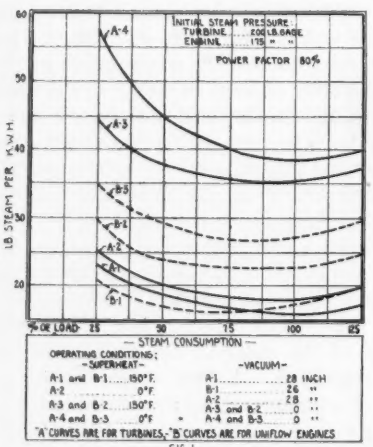
INITIAL STEAM PRESSURE
TURBINE ....200 LB. GAGE
ENGINE ....175 " "
POWER FACTOR 80%
LB. STEAM PER K.W.H.
% OF LOAD
STEAM CONSUMPTION
OPERATING CONDITIONS;
SUPERHEAT
VACUUM
A-1 and B-1 ....150° F. A-1 ....28 INCH
A-2 ....0° F. B-1 ....26 "
A-3 and B-2 ....150° F. A-2 ....28 "
A-4 and B-3 ....0° F. A-3 and B-2 ....0 "
A-4 and B-3 ....0 "
"A" CURVES ARE FOR TURBINES, "B" CURVES ARE FOR UNIFLOW ENGINES

FIG. 1

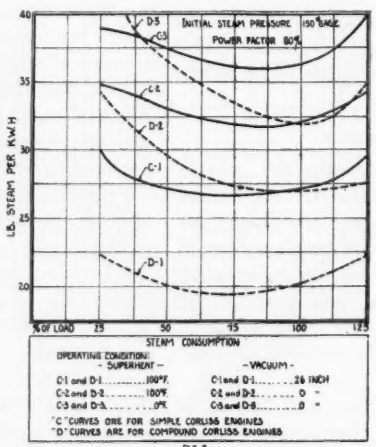
INITIAL STEAM PRESSURE 150 GAGE
POWER FACTOR 80%
LB. STEAM PER K.W.H.
% OF LOAD
STEAM CONSUMPTION
OPERATING CONDITION
SUPERHEAT
VACUUM
C-1 and D-1 ....100° F. C-1 and D-1 ....26 INCH
C-2 and D-2 ....100° F. C-2 and D-2 ....0 "
C-3 and D-3 ....0° F. C-3 and D-3 ....0 "
"C" CURVES ARE FOR SIMPLE CORLISS ENGINES
"D" CURVES ARE FOR COMPOUND CORLISS ENGINES

FIG. 2

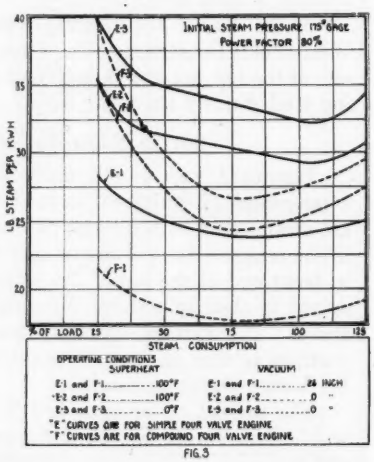
INITIAL STEAM PRESSURE 175 GAGE
POWER FACTOR 80%
LB. STEAM PER K.W.H.
% OF LOAD
STEAM CONSUMPTION
OPERATING CONDITIONS
SUPERHEAT
VACUUM
E-1 and F-1 ....100° F. E-1 and F-1 ....26 INCH
E-2 and F-2 ....100° F. E-2 and F-2 ....0 "
E-3 and F-3 ....0° F. E-3 and F-3 ....0 "
"E" CURVES ARE FOR SIMPLE FOUR VALVE ENGINE
"F" CURVES ARE FOR COMPOUND FOUR VALVE ENGINE

FIG. 3

FIG. 1. AVERAGE STEAM CONSUMPTION OF A TURBINE AND A UNIFLOW ENGINE FIG. 2. AVERAGE STEAM CONSUMPTION CURVES FOR SIMPLE AND COMPOUND CORLISS ENGINES FIG. 3. AVERAGE STEAM CONSUMPTION CURVES FOR SIMPLE AND COMPOUND FOUR-VALVE ENGINES

50 per cent and 73 per cent for a load factor of 75 per cent.

It was figured that the coal to be used contained 13,500 B.t.u. and that it cost $7 a net ton delivered at the plant. The corresponding figures for fuel oil were 18,500 B.t.u. per lb. and $3 a barrel delivered at the plant. The figures covering maintenance are based on data from similar plants in actual operation. Annual fixed charges are assumed at 15 per cent of the investment cost for all plants.

Investment and Operating Costs of a 1500 kw. Central Station Condensing Plant with Superheat, Including Diesel Plant

INVESTMENT COSTS

	Turbine Plant	Uniflow Engine Plant	Simple Four Valve Engine Plant	Compound Four Valve Engine Plant	Simple Corliss Engine Plant	Compound Corliss Engine Plant	Diesel Engine Plant
Real Estate	$8,000.00	$8,000.00	$8,000.00	$8,000.00	$8,000.00	$8,000.00	$8,000.00
Building	137,800.00	187,200.00	158,400.00	161,600.00	164,000.00	173,200.00	107,200.00
Boilers	38,000.00	37,100.00	52,300.00	37,100.00	52,300.00	37,100.00	....
Stokers	10,850.00	10,850.00	15,920.00	10,840.00	15,920.00	10,850.00	....
Condensers	22,900.00	11,880.00	14,550.00	11,470.00	15,050.00	11,880.00	....
Piping	58,000.00	58,000.00	58,000.00	58,000.00	58,000.00	58,000.00	19,000.00
Generating Units	82,500.00	135,700.00	131,500.00	142,500.00	131,500.00	158,500.00	321,000.00
Switchboard	17,600.00	17,600.00	17,600.00	17,600.00	17,600.00	17,600.00	17,600.00
Wiring	13,200.00	13,200.00	13,200.00	13,200.00	13,200.00	13,200.00	13,200.00
Chimney and Flue	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00	18,000.00	....
Forced Draft Fans & Ducts	6,000.00	6,000.00	6,500.00	6,000.00	6,500.00	6,000.00	....
Coal & Ash Handling Eq'm't	34,260.00	34,260.00	35,250.00	34,260.00	35,250.00	34,260.00	....
Engine Room Crane	2,100.00	2,550.00	2,400.00	2,400.00	2,550.00	2,550.00	2,550.00
Feed Water Heater	1,980.00	1,980.00	2,500.00	1,980.00	2,500.00	1,980.00	....
Feed Pumps	4,010.00	4,010.00	4,010.00	4,010.00	4,300.00	4,010.00	....
Equipment Foundations	8,230.00	22,000.00	15,800.00	22,375.00	16,860.00	19,950.00	13,700.00
Oil Filters and Tanks	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	2,500.00	....
Cooling Water Supply	11,060.00	6,470.00	6,800.00	6,470.00	6,800.00	6,470.00	16,100.00
Fuel Oil Storage	....	....	....	....	....	....	9,680.00
Railroad Siding	2,550.00	2,550.00	2,550.00	2,550.00	2,550.00	2,550.00	2,550.00
Total	$479,540.00	$579,850.00	$565,780.00	$560,855.00	$573,380.00	$586,600.00	$530,580.00
Cost per kw. (1500 kw. Peak)	$319.69	$386.56	$377.19	$373.90	$382.25	$391.07	$353.72

OPERATING COSTS

Load Factor 25%

Fuel	$53,655.00	$51,100.00	$59,850.00	$50,610.00	$63,700.00	$51,450.00	$31,200.00
Labor	11,580.00	11,580.00	11,580.00	11,580.00	11,580.00	11,580.00	12,600.00
Lubricants	250.00	500.00	500.00	500.00	500.00	500.00	1,000.00
Supplies	2,800.00	3,300.00	3,400.00	3,300.00	3,500.00	3,300.00	6,800.00
Cooling Water	....	....	....	....	....	....	800.00
Operation (Total)	$68,285.00	$66,480.00	$75,330.00	$65,990.00	$79,280.00	$66,830.00	$52,400.00
Maintenance	7,000.00	8,000.00	7,500.00	7,500.00	7,500.00	7,500.00	8,000.00
Production (Total)	$75,285.00	$74,480.00	$82,830.00	$73,490.00	$86,780.00	$74,330.00	$60,400.00
Fixed Charges 15%	71,931.00	86,978.00	84,867.00	84,128.00	86,007.00	87,990.00	79,587.00
Total Cost at Bus	$147,216.00	$161,458.00	$167,697.00	$157,618.00	$172,787.00	$162,320.00	$139,987.00
Cost per kw-hr.							
Production	$0.0229	$0.0227	$0.0252	$0.0224	$0.0265	$0.0226	$0.0184
Fixed Charges	0.0219	0.0265	0.0258	0.0256	0.0262	0.0268	0.0242
Total	$0.0448	$0.0492	$0.0510	$0.0480	$0.0527	$0.0494	$0.0426

Load Factor 50%

Fuel	$78,400.00	$78,750.00	$94,500.00	$78,225.00	$102,900.00	$83,300.00	$54,750.00
Labor	12,660.00	12,660.00	12,660.00	12,660.00	12,660.00	12,660.00	12,600.00
Lubricants	300.00	550.00	550.00	550.00	550.00	550.00	1,200.00
Supplies	3,000.00	3,500.00	3,600.00	3,500.00	3,700.00	3,500.00	7,200.00
Cooling Water	....	....	....	....	....	....	1,000.00
Operation (Total)	$94,360.00	$95,460.00	$111,310.00	$94,935.00	$119,810.00	$100,010.00	$76,750.00
Maintenance	9,850.00	10,800.00	10,000.00	10,000.00	10,000.00	10,000.00	10,500.00
Production (Total)	$104,210.00	$106,260.00	$121,310.00	$104,935.00	$129,810.00	$110,010.00	$87,250.00
Fixed Charges at 15%	71,931.00	86,978.00	84,867.00	84,128.00	86,007.00	87,990.00	79,587.00
Total Cost at Bus	$176,141.00	$193,238.00	$206,177.00	$189,063.00	$215,817.00	$198,000.00	$166,837.00
Cost per kw-hr.							
Production	$0.0158	$0.0161	$0.0185	$0.0160	$0.0197	$0.0168	$0.0133
Fixed Charges	0.0110	0.0133	0.0129	0.0128	0.0131	0.0134	0.0121
Total	$0.0268	$0.0294	$0.0314	$0.0288	$0.0328	$0.0302	$0.0254

Load Factor 75%

Fuel	$99,750.00	$100,275.00	$123,200.00	$99,750.00	$135,975.00	$107,800.00	$78,450.00
Labor	12,660.00	12,660.00	12,660.00	12,660.00	12,660.00	12,660.00	13,680.00
Lubricants	350.00	600.00	600.00	600.00	600.00	600.00	1,400.00
Supplies	3,200.00	3,700.00	3,800.00	3,700.00	3,900.00	3,700.00	7,600.00
Cooling Water	....	....	....	....	....	....	1,200.00
Operation (Total)	$115,960.00	$117,235.00	$140,260.00	$116,710.00	$153,135.00	$124,760.00	$102,330.00
Maintenance	11,000.00	12,000.00	11,500.00	11,500.00	11,500.00	11,500.00	12,000.00
Production (Total)	$126,960.00	$129,235.00	$151,760.00	$128,210.00	$164,635.00	$136,260.00	$114,330.00
Fixed Charges at 15%	71,931.00	86,978.00	84,867.00	84,128.00	86,007.00	87,990.00	79,587.00
Total Cost at Bus	$198,891.00	$216,213.00	$236,627.00	$212,338.00	$250,642.00	$224,250.00	$193,917.00
Cost per kw-hr.							
Production	$0.01290	$0.01317	$0.01538	$0.01296	$0.01667	$0.01387	$0.01160
Fixed Charges	0.00730	0.00883	0.00862	0.00854	0.00873	0.00893	0.00808
Total	$0.0202	$0.0220	$0.0240	$0.0215	$0.0254	$0.0228	$0.01968

This article covers only that part of the report which concerns the investment and operating costs of a 1500-kw. central station condensing plant with superheat and a Diesel engine plant of the same size. The table given on page 373 covers these conditions for six types of steam-driven prime movers and in addition, a plant in which Diesel engines were used to generate electric current.

Steam pressures were assumed as follows: turbine, 200 lb. per sq. in. gage, uniflow and four-valve engines 175 lb. per sq. in. and for the Corliss engines 150 lb. per sq. in. The vacuum to be maintained on the turbine is 28 in. and on the engines it is to be 26 in. Hg. Superheat is assumed at 150 deg. F. for the turbines, 150 deg. F. for the uniflow engines and 100 deg. F. for the four-valve and Corliss engines.

Reproduced herewith is a typical drawing which shows the steam turbine plant. The general arrangement of all steam-driven plants is similar to the one shown. Curves are also given which show the steam consumption for the various types of units. The Diesel engines were assumed to have the following fuel economy: at 25 per cent of load 0.85 lb. oil per kw., at 50 per cent of load 0.65 lb. oil per kw., at 75 per cent of load 0.62 lb. and at 100 per cent of load 0.59 lb.

Comparative costs of non-condensing plants with and without superheat will be published in near future issues.

What Type of Stoker Drive Should Be Used?

Relative Advantages of Engine, Turbine, A. C. and D. C. Motor Drives Should be Carefully Considered

WHEN, in the process of laying out a boiler plant, the designer is confronted with the question as to what kind of a stoker drive would be best suited for his installation, he must of necessity consider a number of factors

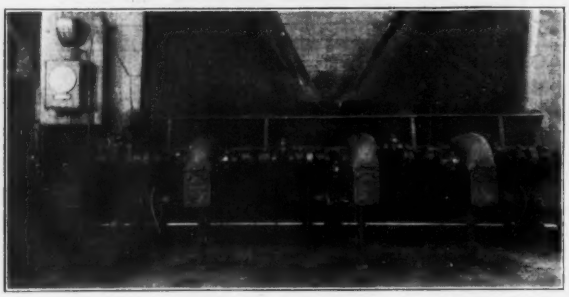

FIG. 1. TYPICAL RECIPROCATING ENGINE STOKER DRIVE INSTALLATION

which have a definite bearing on the ultimate economy of the plant as a whole. Anyone who operates a power plant, for whatever purpose, is primarily interested in keeping his ultimate cost, over a period of years, down to the absolute minimum. This means not only operating costs and fixed charges, maintenance expense and such items but it also means loss of revenue caused by a forced shut-down at an inopportune moment.

Whether this low ultimate cost can be obtained by utilizing the most reliable equipment available even at a considerable advance in first cost or by using less reliable, less efficient and perhaps less expensive equipment, involving greater maintenance costs is a question that can not be decided in a general way to cover all cases. Every installation must receive special attention, must be decided for itself on its own merits, giving due weight to the individual circumstances and the environment in which the unit must function. It is, however, possible to point out some of the most important factors that must be given consideration.

Reliability, insurance against interruption of service, is probably the one factor that must be considered of paramount importance in the operation of a stoker drive in most types of plants. One break-down at a crucial full-peak period might easily cause enough loss of revenue to make it worth while to carry an additional one or two standby drives. Next to reliability, efficiency may perhaps be considered of secondary importance, then first cost, ease of operation, maintenance costs and such items.

In this light let us consider the various sources of power available. There are in general two sources: primary and secondary power. In the first class may be considered the simple steam engine, the steam turbine, the hydraulic turbine, and the rams employed on certain types of stokers, both steam and hydraulic operated. In the second class there are the various types of electric motors, both alternating and direct current. Various characteristics may be obtained in the series, shunt, and compound wound d. c. motors and in the wound rotor, squirrel cage and commutator type a. c. motor.

Steam Engine and Turbine Drives

The force required to operate a stoker is practically constant regardless of the speed, hence a constant torque characteristic of the driving mechanism is a desirable attribute. Unless it is desired that a particular boiler unit should assume a constant block load, the rate of feed of the stoker should be able to follow the steam demand over a continuous speed range from minimum to maximum. This combination of characteristics, constant torque with a continuous speed range is found in the simple steam engine such as illustrated in Fig. 1. This type of prime mover is well understood by the average operator, a fact which tends to decrease the possibility of a shut-down; the construction is rugged and, aside from the occasional attention by an oiler, requires but little care.

One disadvantageous feature accompanying the use of such an engine is that it is necessarily more or less exposed to the dust and grime of the boiler room which considerably increases the normal wear on all the moving parts. The steam consumption of such small units as are required for driving stokers is quite high even on a new engine and, when it has been operating for some time in this atmosphere, the steam consumption soon reaches an abnormally high figure. Unless there is an active demand for exhaust steam, the operating costs will be high.

This brings up the question of station heat balance. If exhaust or extracted steam is not otherwise available to maintain the feed-water temperature at the desired point, it may be advisable to operate the engine simply as a reducing valve.

Steam turbines are being used with success in many plants for driving stokers. They have an advantage over the steam engine in that the steam consumption is somewhat lower. On the other hand, the turbine is essentially a high speed machine and, therefore, reduction gears are necessary. It finds its best application as a constant speed machine; for speeds below the most economical point, there is a marked reduction in efficiency. With all this accessory equipment the initial cost becomes rather excessive, as much as four or five times that of the engine installation.

In plants employing high pressure and superheat the steam turbine stoker drive finds its greatest field of usefulness. A reciprocating engine does not stand up well under these severe conditions.

One particular advantage of the turbine over the steam engine is that the exhaust is free from oil, a condition which permits of the direct use of the exhaust for feed water heating purposes. The drive shown in Fig. 2, consisting of the turbine and a worm reducing gear, can be regulated manually or automatically from 100 to 400 r.p.m. or over a wider range if conditions demand it.

Inasmuch as reliability is of more importance than efficiency in the operation of an auxiliary as important as a stoker, the steam turbine has a considerable advantage, partly on account of the mechanism itself but largely because of the fact that all extra equipment necessary in connection with motor drives is eliminated and with it the extra chance for interruption of service.

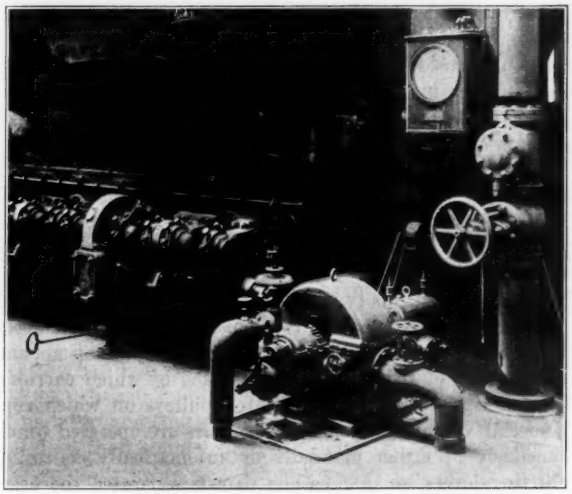

FIG. 2. GEARED STEAM TURBINE UNIT DRIVE

As compared with motors again, the use of turbines saves conversion costs and, whereas the heat consumption of a turbine may exceed by a considerable amount the equivalent heat consumption of a motor, when the ultimate cost figured back to the steam in both cases is considered the difference may be inconsequential.

Another phase of this question that must be taken into account is that with motor drives one prime mover must be kept in operation at all times regardless of outside demands. This means that there may be times when a turbine is operated at a fraction of its capacity simply to keep the auxiliaries going. Independent steam auxiliary drives release the large generator at times of no load.

Line Shaft Drive Simplifies Auxiliary Equipment

In some types of installations it is possible so to arrange the system as to drive a number of stokers from one source of power by means of a line shaft. The advantages of such a system are that it utilizes larger and consequently more efficient prime movers or motors and that it considerably simplifies the equipment. The line shaft is operated through a limited speed range hence this is a factor that need not be taken into consideration in the selection of the motive power. On the other hand, the various stokers in the battery will not always be required to be operated at the same speed, hence means must be provided for effecting a change of speed between the shaft and the stoker. This has usually been accomplished by means of an eccentric and ratchet arrangement so constructed that the radius of action of the eccentric on the ratchet arm could be varied in accordance with stoker speed required.

FIG. 3. BATTERY OF UNIT STEAM RAMS

This system has, in the past, found its largest application in connection with chain grate stokers but it is rapidly being supplanted by the system of individual drives.

Direct Acting Plungers Require But Little Attention

Direct-acting plungers operated by either steam or water pressure have been used successfully in certain fields, particularly in small manufacturing plants to drive stokers having a reciprocating feed. The chief advantage of this type of drive shown in Fig. 3 lies in the simplicity and ruggedness of the construction which commends it for use in locations open to the dust and dirt frequently encountered in boiler rooms. Practically the only wearing parts are the valve mechanism and the piston and rod; all gearing and reduction mechanism is entirely eliminated. The first cost is low and, on account of the rugged construction, the maintenance is comparatively low. On the other hand, the actual cost of operation is likely to be high due to comparatively high steam consumption.

Where water pressure is available, hydraulic plungers may be used. They provide a gradual movement of the plunger but the energy consumption is high. A combination of steam and water is to be found in a plunger recently brought out. It is in reality a steam-actuated, hydraulic plunger; water pressure acts on the plunger piston and the water pressure is created by the action of steam on a connected water column. The admission of steam to the water columns is controlled by a valve on the plunger cylinder, actuated by the movement of the plunger rod. This device combines the advantages of both the steam and

hydraulic systems and it is said to be somewhat more economical in the use of steam.

From the practical point of view there are certain objections to any apparatus in which water is used that can not be well overlooked. Wherever there is a possibility of a prolonged shut down, as for instance over Sunday, there is always the likelihood that the water lines and passages may freeze up in cold weather, unless special precautions are taken to drain them thoroughly. Inasmuch as this operation is subject to the not infallible human element it is possible that a serious freeze-up may occur which will lay up the whole plant.

Hydraulic Turbine Drive is Unique

It may be of interest to note here what influence certain special conditions of operation may have on the selection of auxiliary equipment. At a pumping station now being installed, for instance, the stokers are driven by hydraulic

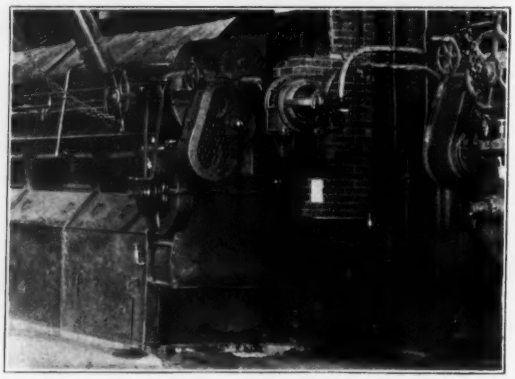

FIG. 4. THREE-PHASE WOUND-ROTOR DRUM CONTROL UNIT DRIVING A CHAIN GRATE STOKER THROUGH A 4-SPEED SELECTIVE GEAR TRANSMISSION

turbines. In this plant are five turbine-driven centrifugal pumps, three of which operate against a maximum head of 450 ft. and two against 154 ft. There are also three low-head pumps which take water from the filter basin and deliver it against a head of 85 ft. The stoker and condensate pump turbines receive their supply from the discharge of the raw water pumps under a head of 95 ft. and discharge into the suction main against a 25-ft. head, realizing a net head of 70 ft. The stoker turbines are rated at 10 hp. and drive the stokers through worm gears. Because of the small amount of power involved, the overall efficiency of these units, figured back to the steam consumption of the main turbine, is said to be higher than that of a small steam turbine.

Several Types of Motor Drives Are Available

In considering the cost and reliability of any motor drive system the transformers or converting equipment must be taken into consideration. Wherever d. c. motors are used, except, perhaps, in certain industrial installations where the main generator supplies direct current, the reliability of the motor-generator set or converter must be reckoned with. Unless a dual drive is used on the stoker, it is usual to provide a standby motor-generator set to take care of any emergencies that may arise. Part of the cost of maintaining this standby equipment must, of course, be borne by the stoker driving mechanism.

The same proposition applies in the case of transformers for a.c. equipment, the additional cost of an extra transformer must be distributed pro rata among all the motors which it may be called upon to serve.

Motor drives, both alternating and direct current, have been widely used for stokers, especially in central station practice where there is an auxiliary bus. Alternating current motors probably make up the larger proportion of stoker motor drives but the direct current motor has been used with more efficient results on many stoker installations. A speed range of at least 4 to 1 is ordinarily required. This range may be had on a d.c. machine by the use of either a shunt field or combination field and armature control. The combination control may permit of a smaller motor but it has the objection that to obtain certain definite speeds the torque requirements must be accurately known, a factor which can not easily be predetermined. The result is that, after the installation has been made, it is frequently necessary to change the resistance grids. Wearing in of a new stoker will also decrease the power requirements and necessitates other changes in the resistance control elements.

The shunt-wound, d.c. motor having only a field control has many desirable features for stoker application. It has a wide and continuous speed range at practically constant torque, a fact which insures a definite speed for a given position of the controller. The unit can be readily arranged for automatic regulation and the efficiency is comparatively high over the entire speed range. Variable speed arrangements and selective gear transmission systems are quite unnecessary.

In order to simplify the electrical control, mechanical transmissions are frequently used to obtain the requisite speed variation in connection with constant speed, two-speed or slip ring induction motors. Of the two types in general use one is quite similar to the usual automobile selective gear transmission. Four speeds forward and one reverse, used to free the stoker of an obstruction, may be obtained by means of a gear shift and hand or foot operated clutch. In this type the speed range is covered in four steps; in the other of the two types mentioned, the speed range is continuous. Essentially, the transmission apparatus consists of two parallel shafts each of which carries a pair of cone-faced, spline-mounted pulleys on which runs a special V-shaped belt. The two pairs are operated simultaneously by either manually or automatically controlled shifting levers, so that as one pair is separated the other pair is brought together, causing the belt to run over a smaller diameter of one pair and a larger diameter of the other, which, of course, increases or decreases the speed ratios between the driving and driven shafts.

Squirrel cage induction motors having two sets of windings to obtain various pole combinations, as for instance 4 and 8, and 6 and 12 which may be used in connection with a properly designed selective gear transmission of say four-speed ratios to give 16 speeds at the stoker shaft. The range is, however, not continuous, consequently the system works at a certain disadvantage in this respect. Because of this feature and the relatively high initial cost of the unit it is not frequently used.

Slip-ring motors provide a satisfactory method of driving stokers with or without the use of selective gears, that readily lends itself to either manual or automatic operation. Such an installation is illustrated in Fig. 4. Here again, however, difficulty is experienced in determining the correct resistance to be used in the secondary circuit. It

can not be calculated with the fine degree of accuracy required and in most cases experiment on the actual installation must be resorted to.

On account of the inherent troubles due to commutator wear and sparking at the brushes on commutator type a.c. motors, they have not been commonly used for stoker drives in the past but during the last few years there has been an increased demand for this type of drive. The brush-shifting type of motor developed to meet this demand has a continuous speed regulation over a wide range without the usual reduction in efficiency encountered in the use of slip ring motors with secondary resistance control. One objectionable feature is that it has certain series characteristics in that a given secondary resistance does not absolutely fix the speed, if for any reason the torque requirements should be altered.

This objectionable feature has, however, been largely overcome in a brush-shifting motor, lately put on the market, having shunt characteristics which hold, under given resistance conditions, practically constant speed at varying torque. These motors have their speed regulated through about 75 per cent of the rated speed by simply shifting the brushes. The location of these brushes also determines the starting current, the starting torque and the direction of rotation. They may be shifted by means of mechanical connection to levers or handwheels or by means of a small pilot motor remote controlled by push buttons, float switch or from the steam pressure. The only exterior device required for connecting the motor to the line is a line switch provided with overload protection.

In a plant which must meet widely varying load conditions, it is not possible so to proportion steam and motor driven auxiliaries as to maintain, at all times, the most desirable heat balance. To permit changes in the operating routine which will maintain the desired heat balance, several important items of the auxiliary equipment are frequently provided with both steam and motor drives. With this arrangement, when there is a lack of exhaust steam for feed-water heating, the turbine drives may be used. When there is an abundance, the motor drive may be cut in.

In starting up a cold plant, there is, obviously, no steam available for operating steam-driven auxiliaries. In such an event, where motor drives are provided and where it is possible to tie in on an outside source of energy, motors may be used to bring the plant up to normal operating conditions.

To determine what type of drive should be used for any given installation, a comparative analysis should be made of all the available systems, including such factors as initial cost, fixed charges on the total investment, cost of operation and maintenance and the adaptability of the equipment to conditions encountered in local operating methods.

Central Station Heating Proves Successful

A Discussion of the Factors Contributing to Successful Systems of Central Station Heating. By H. A. Woodworth*

CENTRAL STATION heating was first experimented upon some fifty years ago and at that stage of the game it was considered a "joke," chimerical in fact as perpetual motion. After many years of poor management, poor insulation of underground mains, and ill proportioned flat rates, the heating game has begun to receive its share of time and attention from the management. This thoughtful consideration conferred of late upon Central Station heating has had its effects upon the ledger, shifting from the debit to the credit side. The once "slip-shod" methods of underground construction have been discarded and today we find that standardized construction with the lowest transmission losses and longest useful life are in vogue. The old flat rate is rapidly being replaced by the meter system which insures an adequate and equitable basis of charge for steam. The result of it all is that steam heating from a central plant is no longer considered an experiment, but today it is as practical as the distribution of gas, electricity or water and is even more welcome than these utilities on account of the many advantages and conveniences offered the consumer.

This experimental period of Central Station heating ranges from the early '90's, when the idea was first conceived until 1902, when the first standardized plants of importance were begun.

The early plants consisted of long lines of pipes of small diameter, designed to carry relatively high pressure, the pipe being imperfectly insulated, without the least consideration as to physical protection against seepage of water. The fundamentals of design, such as minimum back pressure on the engine, drainage of mains by means of street traps, or any other engineering requirements of the present day were not given consideration. Incapable managers paid "coal heavers" a bonus to help them dispose of the coal and chaos was in the saddle. The bankruptcy attorneys declared that central station heating was at fault and it has been all these years in vindicating itself to the prejudiced public. The most glaring faults causing this unsatisfactory condition were inexperienced managers, a low basis of charge for steam, as well as poorly designed and operated systems.

It surely seemed that failure had been stamped on the district heating enterprise for all time to come.

The first standard exhaust steam heating systems were in connection with those plants which generated electricity and utilized the exhaust from the engine for heating purposes. These systems conveyed the exhaust and distributed it to consumers, where it was measured by means of a condensation meter, the waste water passing to the sewer. (On later systems the condensate is returned to the power plant.) The station piping was so arranged that the exhaust might be supplied to the heating mains from all or part of the engines or thrown into the condenser, the heater or the atmosphere during the heating season while, in summer, the whole plant could be run condensing. When the power load was very light, live steam could be delivered through a reducing valve directly from the boilers to the heating mains. The maximum back pressure on most exhaust steam systems varied from 12 lb. in extreme cold weather to 2 lb. in mild weather, delivering from 1 to 1½ lb. pressure at all times at the most remote points on the system.

The district heating plant designed as an independent heating system was a poor investment in its primitive stage

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but it has long since proved to be a good, safe investment. Electric plants have passed through a similar experience but the combination of electricity and steam supply have proved to be a better investment than either one of the two taken alone. With the steadily increasing cost of coal, the electric plant has found it necessary to utilize every available heat unit. The greatest possible efficiency non-condensing is about 9 per cent, while running condensing it is increased to approximately 20 per cent but, in this case, we are still losing a major portion of the energy in the steam, since about 80 per cent of the energy is wasted in order to eliminate back pressure on units. Why not sacrifice the back pressure and sell this 80 per cent of wasted energy? With this in mind, it is not hard to reveal the gains by such a scheme, that is, sale of the exhaust steam as a by-product.

FIG. 1. HEATING LINE OF ONE OF THE FIRST SYSTEMS, (MERCHANTS HEAT & LIGHT CO., INDIANAPOLIS), AFTER 20 YR. SERVICE

For example, a pound of coal of a calorific value, 13,500 B.t.u. put in the furnace will give the following results:

Lost in Ashes	132 B.t.u.		
Lost in radiation from boilers	675 B.t.u.		
Carried off in gas	2970 B.t.u.		
Carried off in auxiliary exhaust	190 B.t.u.		
Lost in radiation and leaks in station piping	212 B.t.u.		
Lost in radiation and leaks in engine	320 B.t.u.	Total	4499 B.t.u.
Converted into power	1251 B.t.u.		1251 B.t.u.
			5750 B.t.u.

13,500 minus 5750 leaves 7750 B.t.u. as the by-product, which amount is rejected to the heating system, and if the 7750 B.t.u. are sold for heating public buildings and residences, then the condensing apparatus of the plant may be shut down during the eight heating months and this otherwise wasted energy sold for a price that can easily be made to pay all power house labor as well as to pay the cost of all coal consumed for generating heat and light.

Back pressure may be built up on the units enough to deliver steam to all consumers on the underground heating system. The units may be regarded as a regulating valve, the steam being reduced from boiler pressure to the required heat main pressure while the electrical energy is generated during this process. With the bleeder type turbine at 4 lb. back pressure it requires about 45 lb. of steam per kw.hr. and, of this amount, it is safe to say that 30 lb. is delivered at the consumer's service. Knowing the electrical load, the maximum amount of steam that may be sold is estimated and the total load in square feet of radiation that can be supplied by this amount of steam is determined. Under ordinary conditions, the exhaust from generating each kilowatt may be depended upon to supply 100 sq. ft. of direct steam radiation under the most extreme working conditions. Knowing the above facts, all of the exhaust steam may be sold during cold weather while, in mild weather, part of the electric load may be run on a condensing unit.

FIG. 2. A DURABLE TYPE OF CONDUIT AND INSULATION FOR UNDERGROUND MAINS

Preliminary Survey of Territory

Design of an exhaust steam heating system begins at the exhaust side of the units and includes all underground heat mains in detail and building equipment in general. The station pipe for this kind of system is practically the same as it is for an independent electric plant; the only changes are that the exhaust to condensers, heaters and atmosphere must be connected to the heating mains. The free exhaust to atmosphere must have a back-pressure valve installed on it and there must be a live steam connection direct from the boiler header to the heat main, the pressure being reduced from boiler to the heat main pressure by means of a suitable pressure-regulating valve. This arrangement permits the use of either exhaust or live steam, or both, as the conditions of operating the plant may require.

Fundamentals of Design

In designing an exhaust steam district heating plant, the following points must be kept in view:

First. There must be a ready market for the steam.

Second. The steam must be sold within the economic limit so that the price may compare favorably with the cost of operating private plants on the consumers' premises.

Third. The manager must have complete knowledge of the details of the business.

Fourth. The station equipment must be arranged with a view to flexibility in the matter of service.

Fifth. The steam must be sold on a meter basis.

Sixth. The system should be planned with an eye to the demands of a future expansion of service.

Location of Load

In the design of underground heating systems, many engineering considerations of a special character are involved. The prospective territory is carefully gone over, the required radiation for each building being approximated and the total radiation in each block determined. In business sections, the prospective business will ordinarily constitute 70 per cent of the total amount checked. In addition to this, one must be capable of judging the future growth of such a territory and proper allowance made for it. Once having carefully determined the demand of each section, the most desirable layout may be decided upon and proper pipe sizes for each locality determined.

Selection of Site

Having the above information definitely determined one's attention must be directed to the selection of a site for a plant. The points that loom up conspicuously in the settlement of this question are as follows:

First. Contiguity of the steam heating and electric business.

Second. Coal and freight rate.

Third. Water supply.

Fourth. Room for expansion of business.

Fifth. Switching facilities.

Sixth. Facility for meeting special conditions.

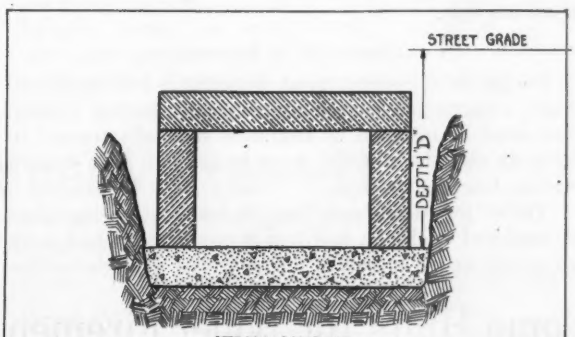
After giving the above points the engineering consideration due them, the heating engineer selects the site, purchasing the one nearest the center of gravity of the heating territory.

Location and Size of Mains

In the design of the main station, the conventional procedure in the matter of power plants is followed. In the design of the outlying system, however, many engineering considerations of a special character are involved. The prospective territory is carefuly gone over and a check of the required radiation is carefully made. As previously explained, when the entire available business in each block is laid off on a map, having the site of a plant, the location of the load, and the total load to be carried, we may easily and intelligently determine location of the mains and the size of pipe required.

The trunk line from the plant to the center of distribution must be of sufficient capacity to handle the total heating load of the entire system. In following this rule, it will be necessary to use larger pipe than if the lines were estimated from a strictly theoretical standpoint but the latter method is lacking in the flexibility of the former rule. This flexibility must be provided for, since the uncertainty of the future business will often call for an unexpected lateral extension, or an overloaded condition at some point that was least expected at the time of the original design. This is why the flexible rule is used by all district heating engineers.

With this understanding, we will proceed further with our design. The necessary plant pressure for central station heating is dependent upon the load to be carried, the maximum permissible back pressure on the prime movers and the distance the plant from the center of distribution. We will require that at least 1 lb. pressure is to be delivered to the most remote points on the system. The belt line as laid out is to be designed for extensions from all points consequently 10 to 14 lb. pressure at the plant will deliver steam to all points of the present layout at ample pressure to permit of such extension. In order to maintain the necessary pressures on the heat lines at all times, there must be a live steam supply made direct from the boilers to the low-pressure heat main. This line will require a pressure-



SIZE	¾"-1½"	2"-2½"	3"-3½"	4"-4½"	5"	6"	7"	8"	10"	12"	14"	16"	20"
WIDTH	18	20	24	28	30	30	30	32	34	36	38	40	42
DEPTH	24	24	30	30	38	40	44	46	52	56	60	66	72
SIZE OF THE CONCRETE — SIDE	6	8	10	12	12	14	14	16	16	20	20	22	26
SIZE OF THE CONCRETE — TOP	6	8	14	16	16	18	18	20	22	24	24	26	34
CONCRETE	2	3	3	3	3	3	3	3	3	3	4	4	4
AIR LINE	¼	½	½	½	¾	¾	¾	1	1	1¼	1¼	1½	1½

FIG. 3. DATA FOR TRENCH DIMENSIONS

regulating valve that shall reduce the pressure from the boiler to the heat line pressure. This live steam line is designed of sufficient capacity to carry the maximum demand heat load. At times when the exhaust supply of steam, as furnished by the electric load, is sufficient, or in case electric units are shut down, this live steam line may be resorted to for the necessary steam supply.

According to tests which the writer has conducted, each square foot of radiation will average 0.28 lb. of steam per sq. ft. of radiation per hour under the most severe weather conditions. The line loss on a system such as is to be designed, will average 10 per cent of the steam sent out from the plant. Allowing 0.30 lb. of steam per sq. ft. of radiation and 10 per cent line loss, you can find the amount of steam sent out.

Plans and Specifications

In drawing up the plans and specifications, the points of most importance are the selection of the best types of insulation, a good system of under-drainage, free travel of mains and perfect drainage of the piping. All pipes should be of wrought iron and of standard weight. The use of flanged fittings is obsolete beneath the ground. All joints are welded. The writer, after several years of experiment-

ing on various heat main insulators, has decided upon 3-in. thicknesses of covering installed with broken joints.

Figure 2 shows the most durable type of conduit. It is a specially made, patented, "Multi-Cell" tile. This is the best conduit for steam mains. The table, shown in Fig. 3, gives the dimensions of trench necessary for "Multi-Cell" tile construction.

Kind of material to be used is of utmost importance, as upon this depends the efficiency and durability of the system. The details of this are brought out in the specifications. These details must be thoroughly understood and the underground conditions familiarized before one can safely estimate the cost of installing a district heating system. After all this precaution, proper allowance must be made for contingencies as well as for the elements.

Cost of steam mains per foot cannot be arrived at as easily as the cost of aerial transmission lines for, in underground construction, we have many unseen obstacles to encounter and pass by without molesting them. Figure 2 illustrates this.

Construction is Important

Design details are of great importance but equally so is the construction of the underground heating system. This must be installed by engineers especially trained in the work and the material must be the best that modern practice has produced.

The writer recommends that the best engineering talent be employed to design and install the underground heating system as the success of the enterprise depends on this.

Some Hints for Boiler Firemen

By Jack L. Ball

IN DESIGNING a steam plant for any small industry, elaborateness is usually cast aside; but for reliability these little isolated plants are second to none. It is true, of course, that purchased electrical energy is rapidly getting a firm foothold and many new industries are using electrical equipment exclusively. While there are many excellent reasons for commending purchased power, one serious fault still remains to be overcome: It is unreliable, especially in bad weather and where there are long transmission lines to contend with. At many places that formerly used steam as a prime mover, the steam equipment has been left intact to be used in emergency cases. This is noticeable where hydroelectric power is used and where the transmission lines are unusually long. It is hardly likely, therefore, that steam will ever be dispensed with for the production of power as long as fuel in some form is available.

All power plant machinery should receive the best of care, but the boiler room should get constant attention, not only for the safety, but from an efficiency standpoint.

Pride a Factor in Boiler Firing

The first and essential requisite of a fireman is pride. Pride not only means cleanliness of person, but it also means that your boiler room should be kept clean. In many cases, this requires a little extra effort on account of coal and ash dust, but use the water hose freely and see how effective it will prove to be.

Keep the firing aisle free from an accumulation of coal. Not only is this unsightly, but it is tiresome for a man to walk about all day on a rough surface. Have a regular place to keep your fire tools when not in use. Packing, spare pump valves and other small supplies can be kept in a small cupboard, or if necessary, in a box. The idea is that often something is needed in a hurry and by using some simple system you can save time by immediately getting that which you need at once.

To be efficient, a boiler must be clean both inside and out. As the tubes of either a fire-tube or a water-tube boiler constitute the major part of the heating surface it is necessary that these should be free from scale and soot, as either of them is a non-conductor of heat and means a direct loss, inasmuch as the heat is not conducted to or absorbed by the water in the boiler.

Infiltration of air through cracks in the boiler setting is another source of much loss that can be easily stopped. These cracks or air leaks can easily be detected by the flame of a torch and either stopped with asbestos rope, or some old magnesia pipe covering mixed with fireclay and water.

Leaks in steam and water lines are mostly visible and audible and easily attended to. Occasionally a large leak develops that cannot be repaired when the line is under pressure. Sundays and holidays are excellent times to look after these repair jobs. A leak, if only a small one, means a direct loss to your employer; many leaks increase this loss and it is a part of the fireman's job to save money for the company whenever possible by stopping the loss or by calling the engineer's attention to it.

Heavy Firing Is Wasteful

Some firemen are in the habit of putting on a heavy charge of coal, thinking that the more coal fired at once the longer they will have to rest between charges. This procedure is absolutely wrong. In boiler practice the idea is to keep a high, even furnace temperature. Heavy firing not only deadens down the fire, but it also allows an excessive amount of cold air into the furnace on account of the necessity of keeping the firedoors open for a longer period of time. It is also conducive to a loss of fuel through smoke which is, in reality, unburned fuel. In an experiment made by the writer that covered days, a more or less even steam pressure was maintained by both the heavy and light methods. When a comparison was made of the two methods it was found that where the heavy charges were used a very noticeable increase in coal consumption resulted; the amount of ash increased one-third by volume and it was noted the refuse contained a large amount of unburned fuel.

Where stationary grate bars are used there is, to some extent, an idea that the fire can be cleaned only by the "kick-over-one-side" method. This method, at the best, is a slow, laborious, fuel wasting way. To clean a fire of this kind quickly and efficiently, allow the fire to burn down a little, at the same time throwing a few scoops of coal back against the bridgewall. After allowing this to burn a little while, take the hoe or scraper, push all the live coals back to the bridgewall and then pull out the ash and clinkers. Next, pull your bank of live coals back over the grates and fire lightly. The writer has completely cleaned a moderately dirty fire in a 6 by 6-ft. furnace in 4 min.

Firemen at the small plants are not always assisted in their work with damper regulators, CO_2 apparatus, steam flow meters, instruments for measuring furnace and stack temperature and the like. Quite often they do not even know the temperature of the feed water. The fireman's job, however, is to generate steam for the plant just as efficiently as he can with what is furnished him. If he is interested in his job, he will strive to improve his practical

knowledge by study. Oftentimes, as has been stated, he has no instruments to assist him so must be guided by observation and common sense. Really good firemen are scarce, hence are usually in demand.

Good Firemen Are Appreciated

It is a mistaken idea that a company does not appreciate a good fireman, although we often hear remarks to the contrary. An engineer will boost you, the manager will consider you one of the most important adjuncts and speak of you with pride, and the company will assure you a life job if you want it. Many men have started up the ladder of success by beginning as firemen in small isolated plants. At a convention of steam engineers not many years ago, the writer talked with many men who held high positions of responsibility in the power plant field and who were rather proud that they got their start, as one man expressed it, "right in a little dinkey, one-boiler outfit out in the sticks."

It is quite impossible to enumerate all those little things that make a good fireman. It is well to remember, however, that the real chance for advancement lies not only in knowing what to do, but in actually knowing the "why" it is done. Study is a wonderful help and to those men who have been denied an engineering education and who are desirous of advancing in the science of combustion, perhaps the greatest field of opportunity in the power plant field, excellent chances are afforded them through some one of the combustion schools that teach that profession through correspondence and who maintain a high standard of excellence. Experiments and the trying out of different methods with your boilers and the careful checking of different results obtained will prove helpful. There is no one set of rules that will fully meet the requirements of every plant; however, find the method that gives the best results in your particular plant and then follow it.

Whether you are or not, the company wants you to be careful and efficient and expects you to care for the costly apparatus as well as the supplies that are intrusted to your care. If you are not interested in your job, are inefficient and unreliable with a "don't care" feeling; if you are working simply for the wages that you receive, well, you had better quit for the reason that you are a shirker and are accepting money to which you are not really entitled. In plain words, you aren't much, if any good. Always remember that fortunate is the man who finds fascination in his work. Perhaps his is the only real success—so few have it.

Diesel Engine Fuel Valves---II

Improved Combustion Results From the Study of Valve Details. By H. F. Birnie and R. C. Baumann

IT MIGHT BE well to compare those valves which use plate atomizers with the Hesselman valve which does not use plates. It must be remembered that in principle all air injection valves are basically the same. Reduced to its elements the valves all attain their objective by placing the fuel oil in the path of a stream of air traveling at high velocity. The injection air at high pressure expands through a narrow nozzle, just as the steam in a turbine expands through the nozzles of the turbine and thereby attains a high velocity and creates a sub-normal pressure at the nozzle. As the air rushes past the stationary fuel oil it rubs and tears minute particles away from the body of the oil and carries them through the orifice and into the combustion chamber.

Conventional plate valves and the Hesselman valve are capable of producing equally good results. A minor objection to the plate valve is that it requires more frequent adjustment of the air injection pressure to suit fluctuations of the engine load. It is more responsive and sensitive to variations in the injection air pressure, hence the difference in the pressure required at no load and at full load is considerable. The plate system is to be credited with means for convenient and ready adjustment to suit different grades of fuel.

Usually it is sufficient to add or remove only one atomizer plate or substitute plates having different sized holes when changing grades of fuel. On the other hand, it is for the same reason slightly more sensitive to changes of fuel viscosity than the designs developed along the lines of the Swedish-Hesselman type. The claim is sometimes made that the Hesselman valve does not require as high an injection air pressure; this is not substantiated in practice. The tendency in the modern plate valves is to use as few plates as possible and thus reduce the injection air pressure required. For most Diesel fuels, only one plate is required if the other parts of the valve are correctly designed. In some cases, plates are omitted entirely and the fuel is deposited directly on the atomizing cone.

Located directly below the plates is the atomizing cone, the function of which is to direct and guide the mixture of air and oil leaving the atomizer plates towards the burner or nozzle plate which is below or on the combustion side of the valve needle seat. The opening of the needle valve must necessarily be small for constructional reasons hence the fuel and air mixture in passing through the valve is narrowed down to a fine, high velocity jet.

This diffusing effect of the nozzle plate is most essential at full load when a great amount of fuel must be burned at each firing and it is paramount that all the oil be brought quickly into contact with sufficient oxygen for its complete combustion. The diffusing is desirable for a second reason. If the narrow jet issuing from the valve is not broken up it acts with a blow torch-like action upon the piston top and causes rapid erosion of the metal.

Piston Top Plays Important Part in Spreading the Fuel Spray

Path of the atomized fuel can best be visualized by imagining each fuel particle to be a minute resilient rubber ball. Of these fuel balls issuing from the valve at high velocity probably the larger part of them first strike the piston top and then continue bouncing between piston top and cylinder head as they are crowded outward toward the cylinder walls. In order to expedite the spreading of the spray, the piston top is sometimes made with a raised point in its center as in Fig. 1.

Often the conventional burner or nozzle plate has one central orifice with sharp inward edges and rounded flaring outer edges. The sharp inner edges aid atomization. Some designs use a special nozzle plate having a number of small holes drilled on a circle rather than one large central orifice. This type of plate is most often used in connection

with the Hesselman valve. The valves used in Burmeister and Wain and Winton engines avoid the use of a burner plate and accomplish the same results by depending upon an inwardly opening fuel needle valve. The French firm Schneider uses, instead of the standard nozzle plate, a cup-like attachment as shown in Fig. 3. This cup projects into the combustion chamber and is always at a high temperature. The hypothesis has been advanced that the high temperature of the cup prevents to some degree the separation of the oil from the air as the spray impinges upon it. The wide angle between the holes should also give good diffusion. It is interesting to note here also that Schneider

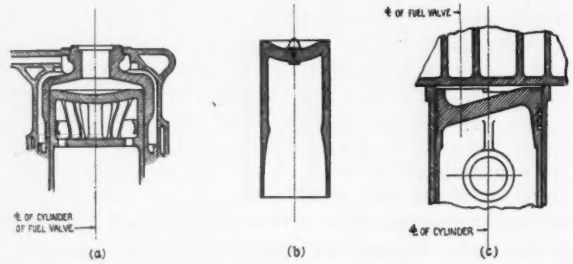


FIG. 1. VARIOUS TYPES OF PISTON HEADS WHICH HASTEN THE SPREADING OF THE FUEL SPRAY

valve does not have atomizer plates but uses instead a quantity of small balls upon which the oil is deposited.

For light loads the diffusion of the spray valve should be reduced so that the fuel particles may be kept away from the water cooled walls of the combustion chamber, as there is sufficient air in the central portion of the combustion space to burn the reduced charges of fuel. This is accomplished by lowering the injection air pressure and by reducing the needle lift.

It is evident, from the diversity existing in successful designs, that, provided the first few fundamental principles are kept in mind and their requirements are fulfilled, the

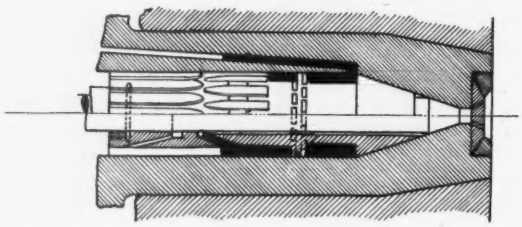


FIG. 2. HESSELMAN VALVE WHICH MAKES USE OF A SPECIAL NOZZLE PLATE

form, shape and detail characteristics of the components of the valve may vary between wide limits and good results will still be obtained. During some recent tests made by the author a great number of combinations of plates, cones and nozzle plates were tried out. A survey of the results obtained showed that equally good indicator cards and efficiency had been obtained with an arrangement consisting of a single atomizing plate, no cone and the standard burner plate and an arrangement comprising three special atomizing plates, one special atomizing cone and a burner plate.

When a new engine is erected in the shops, it is the testing engineer's duty to adjust the fuel valve until the fuel consumption on full, three-quarter, half and one-quarter load falls below the guarantee. When making the adjustments, there are a few essential tenets to keep in mind, as for instance it is axiomatic that the rigging of all the valves, if the engine has more than one cylinder, must be kept identical at all times. In other words, all valves should have the same lead, injection air pressure, nozzle plate, needle lift, number and type of atomizing plates and the same cones. It is also most important that each valve receive the same volume of oil charge per cycle.

Changes made upon one valve alone will affect the whole engine and not only the one cylinder. It is obvious that as the combustion efficiency and consequently the indicated horsepower of the one cylinder is changed the load distribution throughout all the cylinders of the engine must change. It is well when adjusting the valves to select atomizing equipment which will handle fuels of varying qualities without requiring much changing in the valve setting.

Experiments described briefly below are interesting because they give some idea of how the characteristics of the load-fuel consumption curve are affected by changes in the valve setting. The special tests unfortunately were not all made on the same engine as the engines after completing their guarantee test had to be quickly dismantled for shipment to make room for others. All, however, were of the same type, speed and power and otherwise identical. The engines were all Fulton-Diesels of the 3-J type rated at 520 b.hp. at 164 r.p.m. The curves given herein are

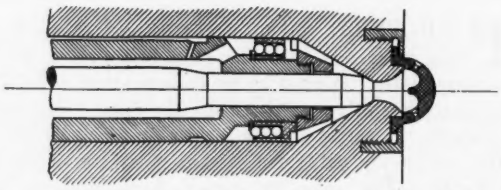


FIG. 3. SCHNEIDER NOZZLE PLATES ARE CUP SHAPED

random experimental data and do not represent best performance of these engines. The object in view was to determine relative performance when using different valve equipment rather than to obtain the best fuel consumption possible.

Three forms of atomizing plates were used: (1) Conventional (2) Modified conventional having three radial prongs (3) standard type plate with three prongs and undercut. The nozzle plate openings were varied but the inner edges were always kept sharp. When the cone alone was used, that is without atomizer plates, there were two passages for the fuel oil and injection air; one along the grooves cut on the outside of the cone body and one between the bore in the cone and the needle stem. The data given below is the result of six different combinations of plates, and cones as follows:

Setting No.	Curve No. on Fig. 7	Opening of Nozzle Plate	Form of atomizer Plate
1	1	0.250 in.	no plate*
2	2	0.266 in.	no plate*
3	3	0.266 in.	one, form No. 1 (Fig. 4)
4	4	0.250 in.	one, form No. 2 (Fig. 5)
5	5	0.297 in.	two, form No. 1 (Fig. 4)
6	6	0.250 in.	one, form No. 3 (Fig. 6)

*Atomizer Cone, same for all.

Fuel consumption curves resulting from these different settings are given in Fig. 7. The injection air pressures required are given for the different points along the curves, mention is also made if the needle lift were full or reduced.

An examination of curve No. 1 will show the lowest fuel consumption at 83 per cent load. The consumption at 63 per cent load is no higher than at full load. The fuel consumption per brake horsepower of the usual oil engine increases steadily from full load to no load, the best economy being obtained at full load. The curve just discussed is desirable for average operating conditions since the engine will run at a reduced load the largest part of the time, hence it should give its best economy under average operating conditions and not at full load.

Curve No. 2 shows a considerably increased rate of consumption although the only change was an increase of the nozzle opening from 0.250 to 0.266 in. or about 7.5 per cent. As curve No. 2 indicated poor atomization because of the higher fuel consumption one atomizing plate of the style termed form No. 1 was added. The valve equipment therefore comprised one atomizer plate, one atomizer cone and a nozzle plate having a 0.266 in. opening. The result is shown by curve No. 3 and represents a distinct improvement although the curve characteristic is different from that of curve No. 1 with its minimum at 83 per cent rating.

When a form No. 1 atomizing plate was used it will be noted that the passageway existing between the needle and the cone was obstructed. In order to determine whether the improved results were due to closing this passage or to the atomizing effect of the atomizer plate, the next step was to cut away most of the atomizer plate, leaving only three prongs and the inner collar. This plate was termed form No. 2. When this plate was used, the passageway around the needle was obstructed just as in the case of curve No. 3 the difference being that practically the entire atomizing effect of the plate had been eliminated by cutting away most of its atomizing surface. The result is shown by curve No. 4.

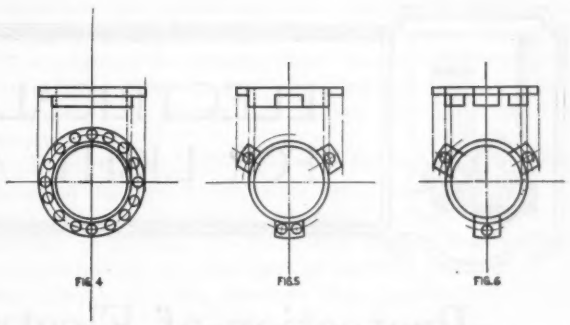


FIG. 4. CONVENTIONAL ATOMIZING PLATE
FIG. 5. MODIFIED ATOMIZING PLATE WITH THREE PRONGS
FIG. 6. STANDARD ATOMIZING PLATE WITH THREE PRONGS AND UNDERCUT

The next logical step was to undercut a form No. 2 plate so that it became a form No. 3 plate. The results of its use, that is a form No. 3 plate, are plotted as curve No. 6. The fuel consumption is not only better but lower injection air pressure is required.

In order to illustrate more clearly the influence of atomizing plates, curve No. 5 is inserted. On previous tests the nozzle plate opening of 0.266 in. had proved to be too large when used without a plate (curve No. 2) and too small when used with one plate (curve No. 3) as in the latter case the combustion had been found to be unsatisfactory and the injection air pressure required was too high hence the nozzle opening was increased to 0.297 in. and two plates, form No. 1 were used. The result (curve No. 5) was an improvement.

In an article which is to appear in a future issue various modern plate valves will be described.

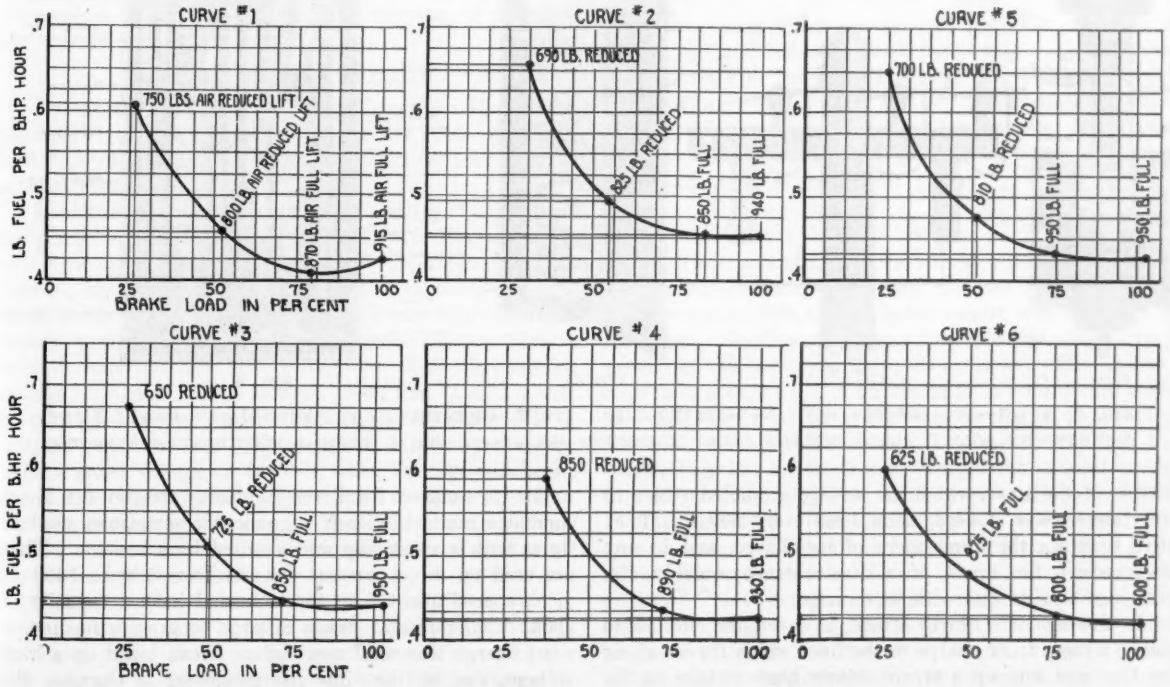


FIG. 7. ENGINE ECONOMY RESULTING FROM THE USE OF THREE FORMS OF ATOMIZING PLATES

ELECTRICAL MACHINERY FOR LIGHT AND POWER

Protection of Electrical Equipment---III

METHODS OF PROTECTING APPARATUS FROM LINE DISTURBANCES BY MEANS OF ARRESTERS, AND REACTORS. BY VICTOR H. TODD.

UNLIKE GENERATORS and transformers, the transmission lines are seldom badly damaged themselves by overload, still they are responsible for the great majority of overloads and high potential shocks which cause damage to the other apparatus. These causes are lightning, which may be either a direct stroke or an induced charge, high voltage surges, due to line switching or synchronizing and, short circuits caused by an internal line dropping across the transmission line or a failure of the line itself, either mechanically or electrically.

Present day lines are seldom subjected to a direct stroke of lightning, as it is customary to run a heavy wire on the topmost point of the tower and sometimes two on the outside of the lines, which are solidly grounded either to every steel tower if used, or at least every 500 ft. They serve to drain the atmosphere of its charge, and in any case, receive the brunt of a direct stroke, quickly discharging it to ground without damage.

In the care of a nearby stroke, however, the effect is to induce a steep front charge in the lines which travels along the line and sets up a tremendously high voltage in the first inductance encountered. Unless properly protected, this would be the end turn of the generator or transformer and if the steep front or rapidly changing charge ever reaches this point, it will undoubtedly puncture the insulation and result in a ground or short circuit.

To prevent this happening, two things are necessary; a lightning arrester which presents an easy path to the ground and a choke which takes the shock, reflects part of it back to the line and so flattens out the portion that does pass, that it cannot cause damage to the apparatus.

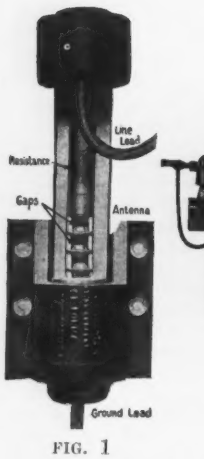


FIG. 1

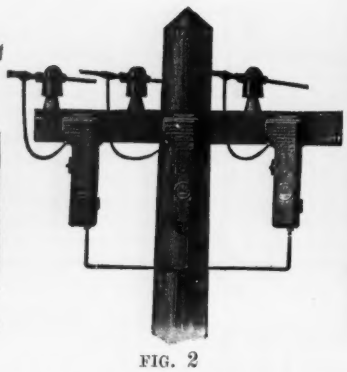


FIG. 2

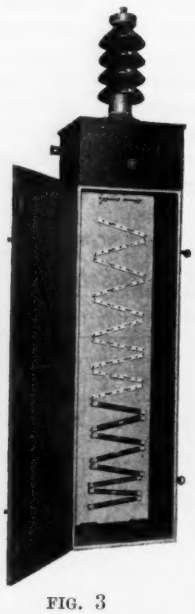


FIG. 3

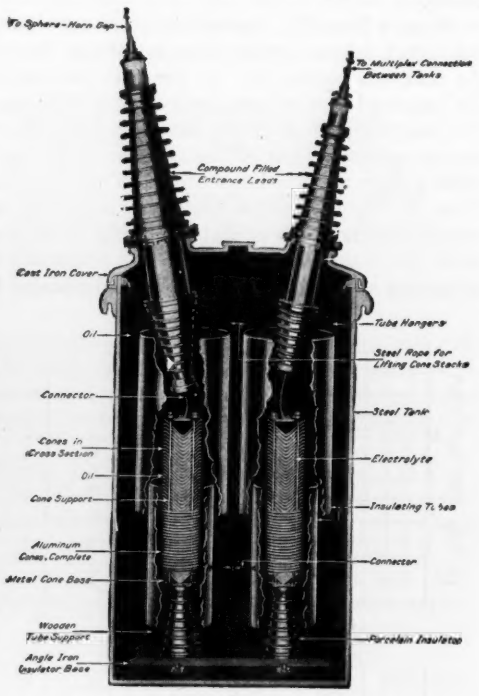


FIG. 4

FIG. 1. MULTI-GAP ARRESTER WITH NON-ARCING GAPS. FIG. 2. ARRESTERS OF THE TYPE SHOWN IN FIG. 1 BUT MOUNTED ON POLE. FIG. 3. MEDIUM SIZED LIGHTNING ARRESTER. FIG. 4. TYPICAL ELECTROLYTIC ARRESTER

In its simplest form, the lightning arrester for direct current circuits is merely a condenser sometimes used in series with a spark gap and shunted by a resistor. They are used on direct current circuits from 100 to 1500 v., d. c., spaced about 5 to the mile and have a capacity of about 1 microfarad. When a surge occurs on the line, it must charge this condenser before it can build up a high voltage, and by the time the condenser is charged, the surge has disappeared.

Next we have the multigap arrester with non-arcing gaps. A view of such an arrestor which may be used on circuits up to 5000 v. is shown in Fig. 1, while three such arresters are shown mounted in Fig. 2.

It will be realized that with an air-gap no current will normally flow but when the lightning surge jumps the gap, then a power arc starts and unless this is quickly extinguished it may result in a dangerous short circuit. The remedy is therefore to place a sturdy resistor in series which will limit the power flow on the first cycle following the arc, and provide non-arcing cylinders to quench the arc. These cylinders are of brass alloy which contains zinc, and zinc vapor has the peculiar property that it allows current to flow only until the voltage reverses; thus when the arc starts and the voltage goes to zero before reversing, the arc is broken and normal operation is resumed. When the cylinders are burnt from continued operation, they may be easily turned, thus presenting a new surface and insuring long life.

In another arrester, the non-arcing metal is in the form of nested insulated cups which hang to the wires on one end and are grounded on the other, thus presenting a cheap, easily installed arrester. Many other simple arresters such as the carborundum and vacuum tube are giving good service.

High Voltage and Capacity Arresters

It is apparent that as the voltages increase and the arc is backed by a large capacity in generators, the arc following a surge will become so great that a small arrester would be damaged by attempting to break so much power. Larger arresters are then necessary and a typical one is shown in Fig. 3, which arrester may be used on circuits up to 39 kv. with an unlimited generator capacity.

The Compression Chamber Multigap Arrester

This arrester consists of a number of gaps between non-arcing cylinders but is enclosed in an almost air tight case so that when a surge discharges, the resulting vapors raise the pressure (compress), thus greatly assisting in smothering the arc.

The Electrolytic Arrester

By far the most reliable and efficient arrester is the electrolytic and this is almost universally used on important lines in spite of the fact that it requires to be charged at least once a day.

It utilizes the principle that if two plates of aluminum are placed in a solution of aluminum hydroxide, a current will flow until a film is formed, the thickness of which depends on the voltage, when the current decreases to a small value. Now should the voltage increase, this film breaks down and a heavy current flows until a film is formed equal to the new voltage or until the voltage returns to normal. It is evident, then, that if such a cell be connected between a line and ground in series with a suitable gap, then if a surge occurs it will jump the gap, impose excess voltage on the cell, when the film will break down, allowing a tremendous rush of current to ground and a discharge of the surge. But the instant the high voltage surge disappears, the film reforms and chokes off the power flow through it.

One such cell will break down at about 250 or 300 v., consequently we find a large number of cells consisting of nested plates until enough are in series to equal the line voltage. A typical arrester of this type is shown in Fig. 4. The film on these plates dissolves slowly in the electrolyte, due to the fact that a gap is in series, consequently voltage is not continuously reforming this film. It is necessary to recharge about once a day (or once a week in one type) by short circuiting the gaps for a few moments, thus placing line voltage directly across the arresters.

Practically all large systems are three-phase but it will be noted that four arresters are used; three are in star to each line and the neutral connected through the fourth arrester to ground. So no matter whether a surge discharges between any two lines, or any line and ground, it will always pass two arresters, thus assuring maximum protection.

The Oxide Film Arrester

Bridging the gap between the cheap multigap arrester and the more expensive electrolytic arrester, requiring daily attention, is the recently developed oxide film arrester. This consists of stacks of circular sherardized steel plates crimped firmly to annular pieces of porcelain, with the intervening space filled with a lead peroxide powder which has a low resistance. When an over potential surge occurs, it breaks down the resistance of the film in one small spot and a power surge follows. Immediately a chemical change occurs in the lead peroxide, changing it to red lead and litharge which has a very high resistance and quickly kills the arc. The next surge breaks through in a new place and is again cut off. Eventually the whole surface will become insulated and the arrester inoperative but they require little attention and will last several years depending on local conditions.

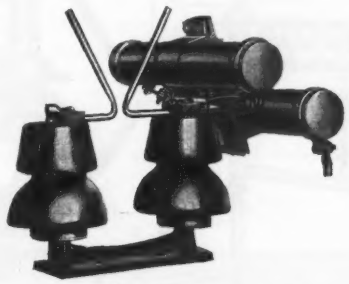


FIG. 5. HORN GAP ARRESTER

Spark Gaps

Of prime importance in connection with the arrester is the spark gap which is connected in series between the line and arrester so that voltage is not continuously applied to the arrester thus constituting a loss of power. The gap is usually of the horn type up to about 15 kv., after which it requires a sphere gap. A gap must have a minimum time-lag; that is, it must allow the surge to pass in the shortest possible time after it occurs. The sphere gap has the shortest lag but on the lower voltages the natural curvature of the rods composing the gap gives the same effect.

Gaps are set so that normal voltage and normal frequency cannot possibly jump but should a steep wave build up a high voltage then it will jump and discharge to ground. The power arc which naturally follows is quickly blown up to the top of the house due to heated air and magnetic effect, and by thus stretching it out, greatly aids the arrester in stopping the flow of power. A typical horn gap is shown in Fig. 5.

In order to discharge high frequency surges and prevent them from building to high potentials, the impulse gap has been developed which may discharge a high frequency surge even though its potential may be only ⅓ or ⅔ of the normal operating voltage. It consists of the regular sphere gaps set for normal overvoltage as usual, but between the gaps, is a small feeler or "tickler" connected as in Fig. 6. With normal frequency, little current flows in the condenser, therefore, the tickler cannot start an arc but when high frequency occurs, then enough power gets to the antennae or tickler to start the arc across half the gap which is quickly bridged across the remainder by the line voltage, thus discharging to ground and becoming extinguished both in the arrester and on the horns.

Ground Connections

A good ground connection is an important part of the arrester. There are several good ground devices on the

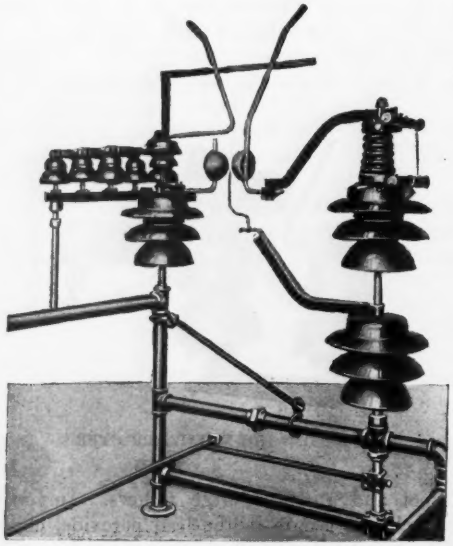


FIG. 6. THE IMPULSE GAP

market but a good one may be made by digging a hole about 4 ft. square as near the arrester as possible and deep enough so that permanently moist ground is encountered. Cover the bottom with about 2 ft. of crush coke or charcoal about pea size. Over this lay a sheet copper plate about 10 sq. ft. and about $\frac{1}{16}$ in. thick. Rivet and solder to this a No. 0 copper wire run entirely across the center of the plate, bring the insulated wire up the pole as straight as possible. It should never be run in an iron pipe as this will greatly choke any high frequency discharge. Cover the plate with two feet more of charcoal and then fill in, using plenty of common salt and water to insure a good connection.

Never throw a plate in running water for a ground; bury it in the mud at the bank of the stream.

Other good grounds consist of driving several pipes about 10 ft. into the ground or disposing large surfaces of copper strap or stranded cable in permanently moist and salted alkalied or acidulated earth.

Grounds should be accurately recorded as to method of making, location and condition and their resistance measured periodically.

Now that an easy path is provided to the ground for high voltage surges, it must be assured that the surge takes this path and does not enter the apparatus. For this purpose a choke is used which receives the brunt of the shock, reflects part back onto the line and so flattens out the part that does pass, that it will not damage the apparatus.

In its simplest form for indoor use and for voltages up to 15 kv., the choke is merely about 20 or 30 ft. of cable wound on an insulated form perhaps 6 in. or 8 in. in diameter. This has very little impedance to normal frequency load currents but has a tremendous choking effect on steep wave fronts and high frequency oscillations.

With few exceptions, the choke is connected in the line between lightning arrester and the apparatus to be protected. The choke may be designed for indoor or outdoor use and is indispensable to the modern system.

Power Limiting Reactors

Closely related to the lightning choke are the power limiting reactors. It will be remembered that with a large generator or bank of generators, a severe short circuit will

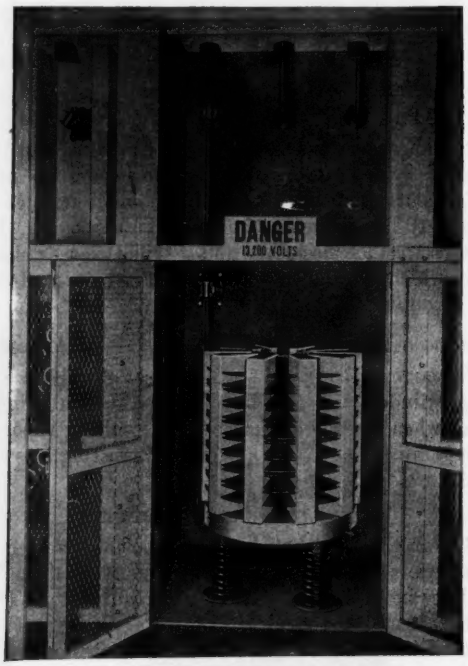


FIG 7. POWER LIMITING REACTORS

draw a tremendous amount of power the first instant, and while the inherent reactance of the alternator quickly lowers this to only a few times normal full load, yet the extreme magnetic stresses of the first instant often cause great damage to the apparatus such as twisting armature coils, blowing apart transformers, opening disconnects, and so forth. In other cases, if the "short" occurs on a comparatively small feeder, even the sustained short circuit current may impose a tremendous overload on the feeder.

In order to eliminate the magnitude of such disturbances, it is customary to use a power limiting reactor. These may be of the iron core with air gaps, or the air core, which simply consists of a large number of turns of heavy wire wound on porcelain, concrete or moulded insulation. A reactor of the molded type is shown in Fig. 7, where it may be seen that the winding consists of copper strap wound on edge.

Before the advent of the modern mechanically strong generator, reactors were usually placed in the generator leads. This formed excellent protection but was bad for service, as every time there was a heavy "short" the bus voltage went so low that synchronous apparatus drifted out of step and often caused a complete shut-down. Since the modern generator has greater ability to stand short circuit shock, and since modern switchboard construction has practically eliminated the probability of a bus bar short, reactors are practically limited to bus bar sections and feeders.

For example, consider a station with any three generators and a bus which may be sectionalized into three sections. These sections would be tied together with power limiting reactors and these in turn would be normally short-circuited by instantaneous trip circuit breakers. In the event of a heavy overload, or even a bus "short" on one section, these reactors would trip instantly thus cutting the reactors into circuit so that the voltage on two busses at least would not fall low enough to lose its load.

These reactors form an essential part of outgoing feeders and are usually connected in the low tension side due to their cheaper cost. In the event of a feeder short circuit, these reactors keep the current within reasonable limits which may be easily broken by the breaker thus allowing a much smaller and cheaper breaker to be employed.

Reactors must not be installed indiscriminately, however, and an individual study must be made of every installation. For example, if too large, they will waste more power than is saved in breaker capacity. Then, too, they must not be used on circuits with high capacity, such as an underground feeder as if the proportion of capacity and inductance should be just right, it might form a resonant circuit which would build up high voltages and cause considerable damage.

Inductive Alternating Current Circuits

AN EXPLANATION OF THE IMPEDANCE DIAGRAM TOGETHER WITH RULES FOR ITS CONSTRUCTION. BY E. K. McDOWELL*

WHEN CONSIDERING alternating current circuits having connected inductive loads, the current supplied to the load by such circuit is caused to lag behind the e.m.f. impressed on the line by some definite angle, ϕ_1. The cosine of this angle of lag is called the receiving-end power factor or load power factor.

In general the properties of an inductive circuit are determined from the receiving-end e.m.f. and the receiving-end power factor as a starting point. The latter determines the phase relation between the receiving-end e.m.f. and current. A further phase displacement between the receiving-end e.m.f. and the sending-end e.m.f. is caused by line inductive reactance effects. The latter point was explained in a previous article (Oct. 15, 1923, issue).

In circuits of this character, which embraces most actual circuits, there are four different e.m.f.'s or e.m.f. components to be considered.

1. Receiving end e.m.f.—Leads current by ϕ_1 degrees, where cos. ϕ_1 is load power factor.
2. Resistance e.m.f.—Resistance drop. In phase with current.
3. Reactive e.m.f.—In quadrature with current.
4. Sending e.m.f.—E.m.f. impressed on the circuit.

It will be seen that the last mentioned e.m.f. is the vector resultant of the other three e.m.f.'s. The vector diagram of these four e.m.f.'s is usually referred to as an impedance diagram and is built upon the current phase as a horizontal or reference axis. Therefore, the phase angle between that axis and the (resultant) sending end e.m.f. is the power factor of the entire circuit; i. e. the sending end power factor. The performance of the circuit is thus determined by this impedance diagram, from which the general line of procedure gets the name of the impedance method. The relations just referred to will be better understood by reference to Figs. 1 and 2.

In Fig. 1 is illustrated a typical inductive circuit with inductive load connected thereto. It will be assumed in the following discussion that the length, size, and spacing of the circuit conductors are fixed; and that the receiving-end conditions are known: i. e., that the load is known as to total kw., e.m.f. at the load, and the load power factor. Obviously the circuit current can be ascertained by means of the following equation:

$$I = \frac{Kw_1 \times 1000}{E_0 \times pf._1}$$

where kw., pf.$_1$ and E_0 represent the total load in kilo-

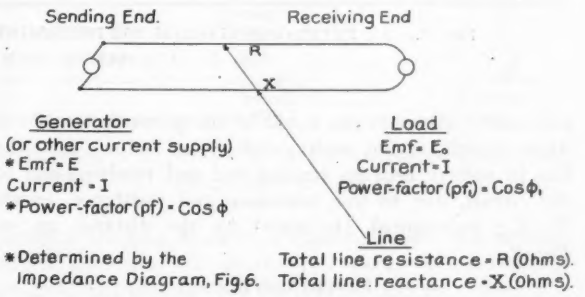


FIG. 1. TYPICAL INDUCTIVE CIRCUIT

watts, the receiving-end power factor and the receiving-end e.m.f. respectively. From the known length, size and spacing of conductors the total line resistance R and total line reactance X are readily ascertainable. The sending end e.m.f. and the sending end power factor are obtained by means of an impedance diagram.

CONSTRUCTION OF THE IMPEDANCE DIAGRAM

As previously noted the receiving end e.m.f. in a circuit like Fig. 1 is not in phase with the current but leads the current by a phase angle, ϕ_1. Accordingly, construction of the impedance diagram is started (Fig. 2) by plotting the receiving-end e.m.f. to scale, as a vector making an angle ϕ_1 with the horizontal base line b; the latter being considered to represent the phase of the current. The receiving-end e.m.f. vector is designated on the diagram as E_0; it is laid off starting from any convenient point (such as K) on the base line b.

It is next in order to add, vectorially, the line resistance e.m.f. E_1 and the line reactive e.m.f. Ex to the receiving-end e.m.f. These e.m.f.-components are readily determined

* Chief Engineer, Donora Steel Works, American Steel & Wire Co.

from the line-constants previously referred to in connection with Fig. 1; E_1 being equal to IR, and being also known as the line resistance drop: likewise Ex is equal to IX and is also known as the line reactance drop. E_1 and Ex are then combined vectorially with E_0, which is done, starting from the outer end of the E_0 vector, by plotting E_1 to scale horizontally because it (being the resistance-e.m.f.) is in phase with the current; then from the end of this E_1 vector the reactive e.m.f. Ex is drawn vertically because it is in quadrature with the current.

Lastly the vector sum, or resultant, of E_0, E_1, and Ex will be the line E, joining the upper end of the Ex vector with K, the starting point. E then represents, vectorially, the sending-end e.m.f.; both as to volts value (by scale) and as to phase-angle with respect to the current. The angle ø, between E and b (the current-phase) then represents the lag in phase of the current behind the sending-

These components would, if known, determine the lag-angle $ø_1$; but it is more convenient and practicable (as a calculation procedure) to assume a suitable value for the receiving-end power-factor, then $ø_1$ is the angle whose cosine is that assumed value. It is therefore not necessary to make use of components a and b, and they are usually omitted from the impedance diagram as practically applied. They are mentioned here mainly to give a clearer conception of the general nature of receiving-end e.m.f.

A modified form of the impedance diagram is shown in Fig. 3, which differs from the impedance diagram in Fig. 2 mainly in that the receiving-end e.m.f. E_0 does not appear as a part of the Fig. 3 vector diagram, but is replaced by its in-phase and quadrature components. These components, which were marked b and a on Fig. 2, are designated on Fig. 3 as E_1-$_0$ and Exx respectively. Otherwise Fig. 3 is the equivalent of the impedance diagram, Fig. 2, which

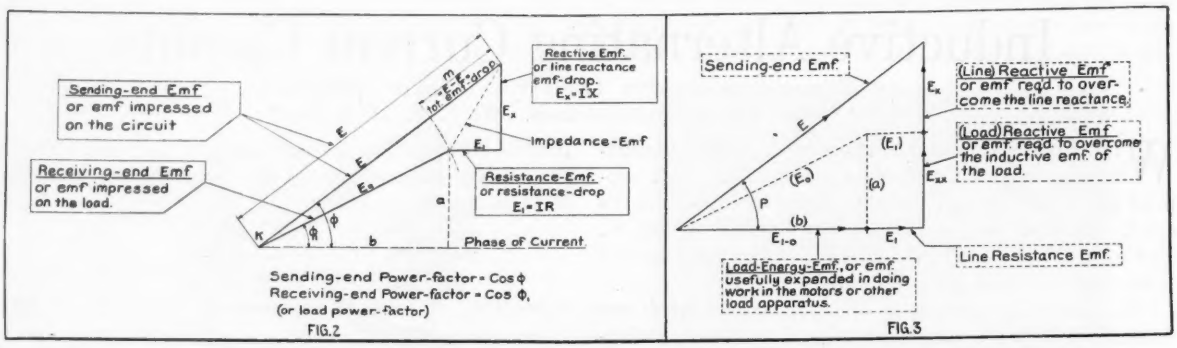

Sending-end Emf or emf impressed on the circuit
Receiving-end Emf or emf impressed on the load.
Reactive Emf or line reactance emf-drop. Ex=IX
Impedance-Emf
Resistance-Emf or resistance-drop E1=IR
Phase of Current
Sending-end Power-factor = Cos ϕ
Receiving-end Power-factor = Cos ϕ1 (or load power-factor)
FIG.2
Sending-end Emf.
(Line) Reactive Emf or emf. reqd. to overcome the line reactance.
(Load) Reactive Emf or emf. reqd. to overcome the inductive emf. of the load.
Load-Energy-Emf., or emf. usefully expended in doing work in the motors or other load apparatus.
Line Resistance Emf.
FIG.3

FIG. 2. AN IMPEDANCE DIAGRAM FOR DETERMINING SENDING END E. M. F. OF AN INDUCTIVE CIRCUIT
FIG. 3. A MODIFIED FORM OF THE IMPEDANCE DIAGRAM

end e.m.f.; therefore cos ø will be the power-factor of the whole circuit, or the sending-end power factor. Also the loss in voltage between sending-end and receiving-end of the circuit, due to line reactance and resistance, equals E—E_0; represented (to scale) by the distance m. on Fig. 2.

Impedance E.M.F.

This is the resultant, or vector sum, of the line resistance e.m.f. (E_1) and the line reactance e.m.f. (Ex.). It appears on Fig. 2 as a (dotted) diagonal vector forming the hypothenuse of the triangle whose other two sides are E_1 and Ex: but it is not necessary to make use of this impedance e.m.f. in connection with the procedure just outlined. Impedance e.m.f. is, however, mentioned here because the term is frequently used as a convenient designation of the combined effects of line resistance and reactance and because the designation of impedance diagram (usually applied to a vector diagram, such as Fig. 2) orginates in this connection.

Components of Receiving-End E.M.F.

On Fig. 2 there are indicated, in dotted lines two components of the receiving-end e.m.f. E_0; one of these components, marked b, being in phase with the current; while the other, marked a, is in quadrature with the current. Component a represents the inductive e.m.f. of the load; and component b represents the e.m.f. usefully expended in doing work in the motors or other apparatus comprising the load, and will be referred to hereinafter as the "load-energy e.m.f."

will be evident; remembering that the vector sum (E in this case) of several component vectors is the same, regardless of the sequence in which the several vectors appear in the vector diagram.

The sending-end e.m.f. E appears as the resultant (vector sum) of two main components, one in phase with the current and one in quadrature therewith. The in-phase component, which can be called the energy-e.m.f., is the sum of the two e.m.f.'s E_1-$_0$, the load-energy-e.m.f., and E_1 the line-resistance e.m.f. The quadrature component, which may be termed the total reactive e.m.f., is the sum of Exx the load-reactive-e.m.f., and Ex the line-reactance e.m.f.

Finally, it should be noted that this Fig. 3 is substantially the same as the vector diagram designated as "Fig. 3" in the article of this series published in the Oct. 15, 1923, issue. In this connection it will be noted that the principles regarding power and power factor of a "load-less" circuit (developed in that article), can be applied with equal validity to a circuit having connected load. This is provided that the energy and reactive e.m.f.'s include both line and load components, as indicated in the Fig. 3 accompanying.

To summarize; the impedance method is a graphical vector-diagram from which is determined the sending-end e.m.f. and sending-end power factor; from known or assumed receiving-end and line conditions. Methods will be outlined in detail in later articles for determining the necessary circuit-constants; and for the application of this impedance method to practical circuit design.

Relation of Auxiliaries to Heat Balance*

System Making Use of a Direct Connected Auxiliary Generator is Suggested.

By A. L. Penniman, Jr.

IN THE LARGER central station steam plants efforts to increase the over-all economy and ease of operation were responsible for the use of motor-driven auxiliaries receiving their power from auxiliary turbo-generators, called house turbines, the exhaust from which is used for feed water heating. This scheme is reliable and economical. It is handicapped by the fact that over a considerable range of load some of the auxiliary power must be taken from the main bus or some of the energy generated must be fed to the main bus. This resulted in transfer motor generators, etc., which were additional complications.

Still greater economy is possible by bleeding steam from the low-pressure stages of the main unit to heat the feed water. The main unit is inherently more economical than any of the smaller auxiliary turbines or the house turbine. In it the steam expands to the lowest pressure compatible with the available condensing water. Obviously, therefore, if steam is bled from a number of successive stages of the turbine and used to heat the feed water which is passed successively through surface heat interchangers, the power obtainable from a given amount of steam will be greatest when that steam is bled at the lowest pressure, and the power obtainable per pound of steam will decrease as the pressure at which the steam is bled increases. Inasmuch as the condensate is usually cooler than the exhaust steam entering the condenser it would be most economical, theoretically, to bleed steam from each of the lower stages of the unit. Practical consideration will probably limit the bleeding to three or possibly four stages, the highest temperature stage being able to deliver relatively hot feed water at light loads. It must be remembered that steam bled from the main unit decreases the congestion in the low-pressure stages of the turbine, thereby improving the total performance of the unit somewhat and also decreases the duty on the condenser.

It is quite probable that still greater amounts of low head heat can be bled from the turbine prior to rejection to the condenser and used to preheat combustion air for the boiler furnaces. While bleeding steam to preheat air is somewhat novel and requires some further development of heat interchangers for this purpose, it shows considerable thermal gain. Present types of stokers using forced draft can handle air up to a total temperature of several hundred degrees F. without any great difficulty. Complications would undoubtedly result from the attempted use of 300 deg. air on pulverized coal-fired furnaces where air-cooled furnace walls are used. In the writer's opinion, however, the air-cooled powdered coal furnace is destined to be short lived, due, first, to the fact that it is obviously uneconomical to allow high head heat, which should be utilized directly for generating steam, to be used for preheating furnace air when there is so much low head heat readily available; secondly, the air-cooled furnace has not been entirely successful, the furnace maintenance undoubtedly being very high and the time the boiler is out for furnace repairs must be a considerable percentage of the service hours. The solution of this question would seem to lie in the development of a boiler and furnace so designed that the water heating surfaces absorb a large percentage of the heat which is now taken up by the furnace walls. This will allow of still higher furnace temperatures with the attending increase in efficiency.

It would, therefore, seem that the greatest opportunity for economy lies in the use of power from the main unit for auxiliary drive, this power being applied as directly as possible, together with the use of the maximum economical amount of low-temperature steam bled at several points from the main unit. The question now arises as to whether this scheme provides the essential flexibility and ease of operation.

By the use of motors it is possible to obtain compact drives, reduction gear troubles are eliminated and the mass of auxiliary steam, exhaust and water-cooling pipes is eliminated. Where d.c. motors with field control for speed variation are used, there is no appreciable decrease in economy of the drive with decrease in speed. When properly designed ball bearings are used, practically no attention is required and the units may be started, stopped or the speed varied from remote points. The steel industry has investigated the ball-bearing motor very thoroughly and has made out a very strong case in its favor. Due to their location, it is desirable to be able to control the speed of forced and induced draft fans and the stoker and clinker grinder motors from the boiler room firing floor, and they are usually so located as to make it impracticable to give them relatively continuous attention without having special attendants at the several elevations where they are located. Boiler-feed and house-service pumps should also be capable of operating under the control of automatic regulators with a minimum of attention. Variable-speed d.c. motors lend themselves to this form of control just as readily as do steam turbines without the attendant change in economy with change in speed and without the attention and troubles incident to turbine packings, bearings and the possibility of damage due to overspeed on account of loss of load.

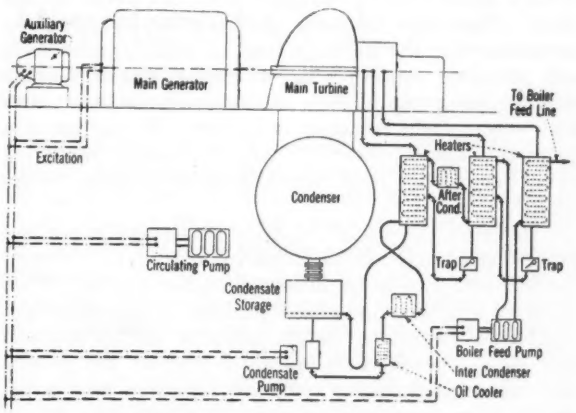


DIAGRAM OF A 25,000-KV. A UNIT WITH DIRECT CONNECTED AUXILIARY GENERATOR

When the extra storage of boiler water is located in the hot well of the condenser and the makeup admitted directly to this hot well it is feasible to keep the water in the hot well at the temperature of the exhaust steam by raising

* Abstract of a paper delivered at the Midwinter Convention of the A. I. E. E., Philadelphia, Feb. 4-8, 1924.

the temperature of the hot well by the condensate from the lowest temperature feed heater, plus some additional steam bled from the last stage of the main turbine when necessary. This eliminates the use of de-aerating apparatus and makes possible the location of the make-up float valve so that it is readily accessible to the condenser attendant who can also look after the boiler feed pumps. The division of duty between the hot-well pumps and boiler-feed pumps can be so arranged as to allow minimum water pressure on the closed heaters compatible with reliable operation. The hot-well pump can be run at constant speed, the total speed variation being taken care of by the boiler-feed pump. The duty on the circulating pump can be varied to compensate for changes in load and of circulating water temperatures. This eliminates the necessity for the use of two pumps of reduced size, one being used for cold water or light loads, two for warmer water and high load, as it is possible to obtain somewhat better performance by using one pump and varying the speed. Where two pumps are used for added reliability it is more economical to run both at reduced speed than to shut one down and speed up the other. Practically the same reliability can be secured by interconnecting the discharge lines on adjacent condensers and providing somewhat larger driving motors, thereby enabling one pump to serve two condensers in emergency with only a slight reduction in vacuum. By the use of a properly-designed motor the large low-speed circulating pump becomes the most reliable piece of auxiliary equipment.

The static or steam jet type of vacuum pump has proved exceedingly reliable in marine service and is becoming increasingly popular in central station service. When equipped with inter and after condensers, using condensate, and located respectively before and after the low-temperature bleeder heater, they provide a compact and reliable unit whose performance compares favorably with a hydraulic or reciprocating air pump at a somewhat smaller first cost, and should show a lower maintenance cost and required less attention than either of the other types. The air and non-condensible vapors from the bleeder heaters can be discharged directly to the inter-condenser, thereby lowering the duty on the primary jets, which should use the minimum of steam possible as it is desirable from an economical point of view to do nothing which will limit the amount of steam bled from the main unit to the low-temperature heater. Most of the operating difficulties experienced with steam jet air pumps have been due to poor performance on the part of the reducing valve supplying steam to the jets. This may be entirely eliminated by the use of a properly-designed orifice installed in parallel with either a hand or solenoid operated valve which may be opened either manually or automatically in case of a drop in steam pressure.

Since stage bleeding together with electric drive offers opportunity for higher efficiency with a maximum of flexibility at a cost as low or lower than with any other form of auxiliary drive, it now remains to provide an arrangement for obtaining power from the main units in such a manner as to guarantee continuity of auxiliary power supply eliminating all chance of trouble on the main bus being transmitted in any manner to the auxiliary bus.

Classification of Auxiliaries

All power plant auxiliaries fall into three general classes with respect to the necessity of their having a continuous power supply.

First, equipment which does not require a continuous power supply, such as coal and ash handling equipment, circulating water screens, sump pumps, machine tools, etc. This class of equipment can be eliminated from the present discussion, as continuity of service is not essential.

Second, the auxiliaries which are needed only when the station is carrying load and which have to be shut down in case of an interruption which greatly reduces the plant load. To this class belong forced and induced draft fans while coal feed and clinker grinder drives might well be included as they are normally supplied from the same circuits as supply the fans. As it is essential to check the fires as soon as a general interruption occurs it is an advantage to have your motors trip out due to low voltage. Where automatic starting panels are used, the service is automatically restored as the main bus voltage comes back. In actual practice following a general interruption the station load does not come back immediately after the restoration of full voltage; usually it is at least ten minutes after the restoration of service before the load is normal. This allows ample time for furnace conditions to become normal. Where the nature of the interruption is such as to result in low frequency and somewhat lowered voltage, trouble may be experienced in holding the motors on the line due to the operation of the low-voltage relays. This can be readily overcome by arranging to throw the affected motor controls on the station control battery. The individual controllers can then be brought up to full speed setting until the trouble is cleared, should this be necessary. Where the total number of boilers is comparatively few the contactors can be provided with a mechanical latch which will hold them in the full-speed position.

It is, of course, essential that the proper safeguards be used to minimize interruptions due to failure of the transformers, circuits and switching equipment between the main bus and the several motors.

The writer has operated a fairly large generating station for about 5 yr. where the boiler auxiliary drives were fed from the main bus. There have been in that time the usual number of system interruptions and disturbances without in a single instance causing any embarrassment due to inadequate power for the stoker fan and coal feed motors. It is the regular practice to have in service two banks of transformers either of which is of sufficient capacity to carry the essential service. The two transformer banks are supplied from either end of the main bus, each serving one-half of the auxiliary circuits and the other plant auxiliary load. The transformers are protected by necessary relays. The switches are so interlocked that if either high-tension transformer switch opens the corresponding secondary switch opens which in turn causes the switches supplying the non-essential auxiliary circuits to trip and parallel the two sections of the low-tension station service bus.

Third, the auxiliaries, which it is essential to keep in service in order to insure continuity of service and which it is essential to keep in service during times of interruption, are the exciters, boiler feed pumps and circulating pumps. Where the boiler-feed make-up storage is a part of the condenser hot well it is also essential that the hot-well pumps be kept in service.

The service for this third class of auxiliary drive can be most economically and advantageously supplied by a separate generator connected directly to and driven by each of the main turbine units.

Direct-connected exciters have been in quite general use

for a number of years and have been so satisfactory that there seems to be no reason why the size of this piece of apparatus should not be increased sufficiently to take care of the additional load imposed by the so-called essential auxiliary drives. This auxiliary generator need be relatively small, in fact only about 2½ per cent of the capacity of the main unit. This arrangement will require, as does the direct-connected exciter some auxiliary source of power for starting up. This can be taken care of by a motor generator, supplied from the house service transformers which if necessary can be equipped with a non-condensing turbine, exhausting to atmosphere, for starting up in case of a complete shutdown of considerable duration.

In the accompanying illustration is shown such an arrangement for a 25,000-kv.a. unit. The auxiliary generator is rated at 500 kw., 250-v. direct current. A 3000-gal. water storage will be provided in the condenser hot well. Three-stage bleeding will be used, the condensate from the high and intermediate temperature heaters will be trapped back to the next lower-temperature heater while the low-temperature heater condensate will be trapped back to the hot well where it will be used to heat the condensate and make up to the boiling point in order to drive off entrained air.

It will be noted that this scheme provides auxiliary power from the most efficient source, allows of the most economical scheme of feed heating without any complications. The auxiliary wiring is on the unit principle, the auxiliaries and generator being grouped together do not require long runs for low-voltage auxiliary feeders and there is no transformation loss in obtaining direct current for these drives. Careful analysis would seem to indicate that this scheme provides the necessary reliability without calling for any compromise that affects the economy of the general layout, at a first cost no greater, if not actually less than any of the arrangements in general use, with a maximum of flexibility of operation at varying loads, with a minimum of operating attendants.

Investigation of Powdered Coal

General Observations of Practical Value Made During a Series of Tests Under Various Conditions

DETERMINATION of the overall boiler efficiency which could be obtained with pulverized coal under various conditions of furnace operation and with coal of different fineness and moisture content, is reported in a recent bulletin of the Bureau of Mines.

This report represents the results of 36 tests made on a 468-hp. Edge Moor boiler at the Oneida St. station of the Milwaukee Electric Railway & Light Co. Illinois coal was fed to the furnaces through feeders and burners as designed by the Locomotive Pulverized Fuel Co. Twenty-nine of the tests were of 24 hr. duration each, three of 16 to 18 hr. and four of 12 hr. duration each.

Deductions which have been drawn from these tests are that the (1) rating that can be developed efficiently by a boiler depends almost entirely on the size and shape of the combustion space. This space is most effective if so arranged as to give the flames the longest possible travel through the furnace.

(2) With this type of furnace and burners the most efficient rate of combustion is 1 to 1½ lb. of coal per hr. per cu. ft. of combustion space. Good results can be obtained between 0.6 and 2 lb. of coal per cu. ft. per hr.

(3) Combustion seems to be completed more rapidly if the flames impinge on hot refractory material but such impingement causes excessive slagging and consequent erosion of the refractory.

(4) Spreading burners seem to have caused less slagging and give better results at high rates of combustion than round burners. Slagging depends upon the fusion point of the ash, furnace temperatures and the percentage of CO_2. The ash from Illinois coal becomes soft and sticky at about 2000 deg. F. and slag begins to form when the CO_2 exceeds 10 per cent and the rate of combustion exceeds 1.3 lb. of coal per cu. ft. of combustion space per hr. Attempts to cool the furnace bottom by the introduction of air shortened the flame travel with the result that solid carbon passed out of the furnace. Erosion of brickwork can be greatly reduced by keeping the flame from striking against it.

(5) Efficiency of combustion is not affected to any appreciable degree by increasing the coarseness of coal so that only about 65 per cent passes through a 200 mesh screen.

(6) Undried Illinois coal containing as much as 7 per cent moisture can be fed steadily by the feeders and burned efficiently in the furnace; it can also be moved by screw conveyors. The coal begins to pack in the feeders and bins when its moisture exceeds 7 per cent although it seems to burn as well when it reaches the furnace. The only difficulty of burning undried coal is more difficult ignition when a fire is started with a cold furnace.

The boiler upon which these lists were made was 15 tubes high by 16 tubes wide, set with vertical baffles with three gas passages. A superheater was provided between the 1st pass and 2nd pass. The furnace was originally as shown in Fig. 1, the shelf-like projection at the front near the bottom was necessitated because of the presence of an old conveyor which could not be removed. Coal was fired vertically downward through two burners from the furnace roof, the flames traveling down in the front part of the furnace and upward in the rear half.

Sixteen tests were run, all of which proved the impossibility of running the furnace with low excess air without the ash fusing at the bottom of the furnace. The tests which followed were made with various arrangements of water screens used to cool the bottom of the furnace. This coil by partly screening the bottom from the radiation of the flame and by absorbing radiation from the bottom kept the temperature of the bottom below that of the fusion point of the ash. It was found advisable to remove the sloping portion of the rear wall because the molten ash flowed from it and over the coils placed in the bottom of the furnace.

Further difficulty arose from the flames impinging upon the front shelf. This problem was solved by covering the shelf with a water screen. These water screens absorbed heat at the rate of 19,000 to 41,000 B.t.u. per sq. ft. of total heating surface per hour.

Round burners were used for the first 26 tests. These burners were two in number and were set on 10½-in. cen-

SUMMARY OF RESULTS OF TESTS WITH PULVERIZED COAL

Test No.	Over-all efficiency, per cent.	Total capacity (heat output), per cent of rating of boiler and coil.	Coal burned, pounds per hour.	Coal burned per cubic foot of combustion space, pounds per hour.	Carbon dioxide in flue gases, per cent.	Excess air, per cent.	Temperature of flue gases, °F.	Arrangement of furnace, condition of coal.	Condition of ash at bottom of furnace.
	1	2	3	4	5	6	7	8	9
1...	78.0	113	1,923	1.34	11.4	54	499	Round burners; round arch; sloping rear wall; no cooling coil.	Soft and sticky, but did not run. Removed with some difficulty at end of each test.
2...	77.8	111	1,944	1.36	11.8	50	516		
3...	75.8	99	1,735	1.23	10.0	78	506		
4...	73.1	117	2,167	1.51	9.3	92	531		
5...	75.1	105	1,880	1.32	11.5	54	501		
6...	78.7	110	1,841	1.29	12.4	43	505		
7...	78.3	112	1,868	1.31	11.7	52	511		
9...	77.7	118	2,001	1.40	13.2	36	501		
10...	81.6	111	1,796	1.26	12.1	47	497		Fused and ran like water. Dug out after furnace was cooled.
11...	80.7	113	1,845	1.29	13.1	37	500		
12...	79.8	110	1,798	1.26	13.9	28	493		
13...	82.8	112	1,783	1.25	14.3	25	476		
14...	81.2	117	1,860	1.30	14.4	24	489		
15...	82.3	126	2,020	1.41	14.5	24	513		
16...	79.7	133	2,161	1.51	15.1	17	496		
17...	79.7	122	1,983	1.39	14.3	26	519	Same as above, but with cooling coil shown in Fig. 9.	Ran down from rear wall over coil; free at bottom.
18...	80.3	114	1,869	1.31	14.6	22	524		
19...	77.5	132	2,218	1.55	14.9	19	529		
21...	77.9	116	1,983	1.26	15.9	8	541	Cooling coil shown in Fig. 10.	
22...	79.1	120	2,040	1.30	15.0	19	532	Perpendicular back wall. Cooling coil shown in Fig. 11.	
23...	80.2	108	2,009	1.28	14.7	21	542	Same as test 22, but with cooling coil shown in Fig. 12.	Fused in center of furnace.
24...	79.8	127	2,115	1.35	14.8	21	542	Same as test 21, but with cooling coil shown in Fig. 13.	Dripped from walls; free at bottom.
25...	73.8	157	2,705	1.73	15.4	14	590		
26...	76.5	158	2,717	1.73	15.0	17	599		
27...	73.8	163	2,584	1.84	14.6	19	603		
28...	81.9	110	1,756	1.10	14.1	28	517	Flat burners, flat arch, perpendicular rear wall, no coil.	Ran from walls; bottom soft; difficult to remove.
29...	84.2	107	1,681	1.05	14.9	19	492		
30...	78.8	174	2,903	1.81	15.4	13	610		
31...	82.7	125	1,973	1.23	15.5	17	483		
32...	81.0	116	1,862	1.16	15.3	18	457	Same as test 30, but with cooling coil shown in Fig. 14; coarse coal.	Soft and sticky; easily removed.
33...	81.7	127	2,004	1.26	15.8	13	472		
34...	81.9	116	1,882	1.18	15.1	17	470		
35...	82.7	112	1,753	1.09	14.6	23	488		
36...	81.7	112	1,866	1.16	15.5	17	484	Same as test 30, but with cooling coil shown in Fig. 15; undried coal.	
37...	80.4	105	1,785	1.12	15.8	15	466		
38...	80.3	124	2,171	1.36	15.4	17	514		

ters. The later tests were run with two flat burners spaced on 26½-in. centers. The round burners were 3½-in. standard iron pipe. The discharge end of the flat burners were 13½ in. long by ¾ in. wide; this form of nozzle exposed a much larger surface for mixing with the additional air and for absorbing radiation from the flame than did the solid stream from the round burners.

Feeders consisted of revolving screws attached to the bottom of the feeder bins. Each burner was supplied by a separate feeder. At the end of the feeder a current of air, under about 6 in. of water pressure, picked up the coal and carried it through a 3½-in. pipe to the burner. A small paddle wheel attached to the end of the screw shaft helped to mix the coal and air.

During the progress of these tests it was found that the use of the soot blowers about once every 3 hr. kept the flue gas temperatures lower than when they were used at longer intervals. In working up this test two calculations were made, based on the flue gas analysis. In one calculation no allowance was made for the sulphur in the coal and all the gas absorbed in the potassium hydroxide solution was assured to be CO_2. In the second calculation, allowance was made for the sulphur in the coal and the flue gas was split into its constituents of CO_2 and SO_2. The difference between the results calculated in the two ways is small and may ordinarily be neglected.

Importance of Size of Coal

It is ordinarily understood that good efficiency can be obtained with powdered coal when the coal is pulverized to 95 per cent through a 100-mesh screen and 85 per cent through a 200-mesh screen. During tests 32 to 35 inclusive the coal was fed coarse, sometimes as low as 64 per cent through a 200-mesh screen. These tests compared with tests 28 to 31 inclusive, in which the same furnace equipment was used, show that the increased coarseness of the coal did not appreciably lower the efficiency and that the losses were about the same in both cases. As a matter of fact, the coal in both groups of tests was made coarser than is usually specified, which would tend to show that completeness of combustion seems to be more a matter of furnace and burner design and of properly supplying air rather than the fineness of coal. If large pieces of coal fell to the bottom of the furnace they continued to burn because the refuse removed from the bottom of the furnace seldom contained a trace of combustible.

In order to determine what effect moisture in the coal had upon the successful burning of pulverized coal, tests 36, 37 and 38 were run with undried coal containing 8 per cent moisture. The results show that the completeness of combustion were as good as with dried coal. There was no loss from CO in the flue gas and the losses caused by combustible in the refuse average only 0.3 per cent for the three tests which is actually less than the average with the dried coal.

Losses due to moisture in coal increased 0.5 to 0.6 per cent, or at the rate of about 0.1 per cent for every 1 per cent of increase of moisture in the coal. The average decrease in the efficiency of the boiler for the three tests is

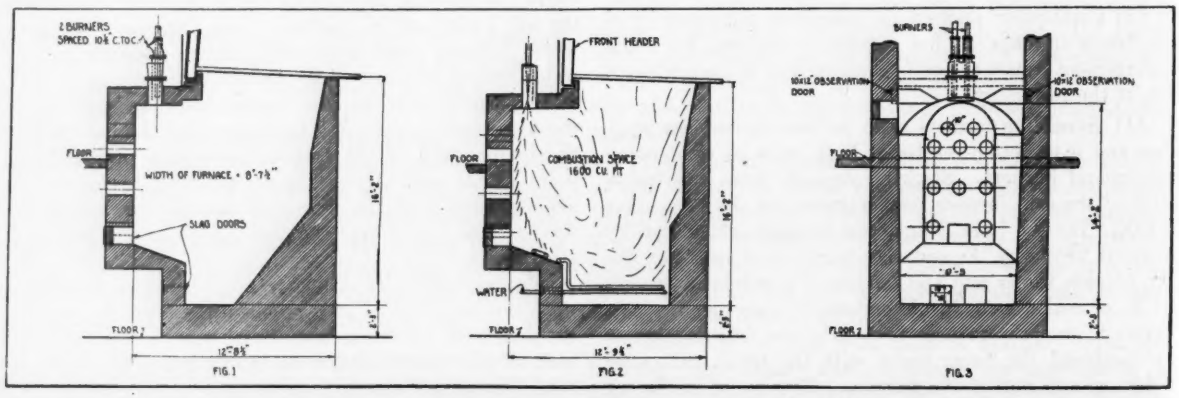


FIG. 1. CROSS-SECTION OF THE ORIGINAL FURNACE. FIG. 2. REAR SLOPING WALL REMOVED AND WATER SCREEN INSTALLED. FIG. 3. INSIDE FRONT VIEW OF THE FURNACE WITH ROUND BURNERS.

0.7 per cent, which checks closely with the increase in the losses due to increased moisture in the coal. It therefore seems unnecessary to dry coal to 1 per cent of moisture in order to get good boiler efficiency.

Fire Hard to Start With Moist Coal

Undried coal burned efficiently and without difficulty when the furnaces were hot. With a cold furnace the undried coal did not ignite readily. As a matter of safety it may be said that the accidental ignition of dust from moist coal will burn with a sluggish action and it does not have the tendency to flare or explode as would be the case with dry coal dust.

One obstacle to the use of undried coal was in moving the coal by screw conveyors. The coal packed in the casing around the screw and caused the pins of the couplings of the conveyor shaft to shear off. A condition which must be avoided is that of storing for any length of time undried pulverized fuel. It will harden and cake, causing difficulty in its removal from the bin. When dried coal is pulverized, new surfaces become exposed and the moisture on these surfaces is vaporized. Then the spaces between individual particles of coal are saturated with vapor. In a cubic foot of pulverized coal only about half of the space is actually occupied by coal, the other half is merely air saturated with water vapor. After the coal reaches the bin, its temperature begins to drop with the result that some of the vapor condenses. The greatest condensation takes place where the temperature is lowest and where the partial pressure of the vapor is lowest, therefore, steam from the interior of the bin will flow continuously to the walls, condense and run down.

This moisture forms a paste with the pulverized coal which impedes its flow and distribution. In steel bins, because of the high conductivity of steel, coal will cool more rapidly than in concrete bins. Not only does concrete have a much lower conductivity but the walls are thicker than a steel bin, therefore, coal in a concrete bin cools slowly. Pulverized coal bins should be made of concrete and the coal should be delivered to them at as low a temperature as possible.

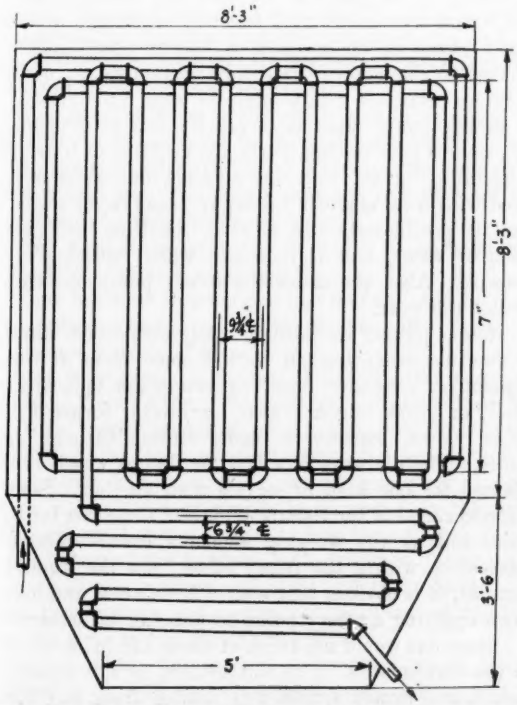


FIG. 4. COOLING COIL OF 2 IN. PIPES. TOTAL AREA OF PIPES 30 SQ. FT.

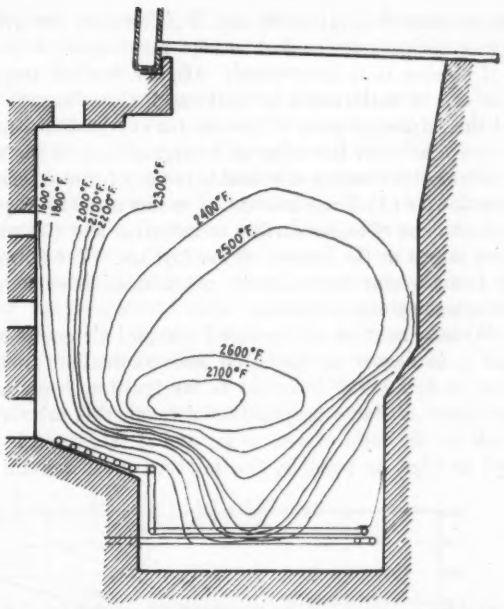


FIG. 5. ISOTHERMALS IN FURNACE. CO_2 IN FLUE GAS 15 PER CENT

Furnace Temperatures

Temperatures in the furnace were measured by rare metal thermocouples and an optical pyrometer. The zone of highest temperature was at a point a little above the inner edge of the shelf and at about the point where the flame bends upward. The position of this zone is determined partly by the intense rate of combustion as the gas eddies in burning up and partly by the fact that up to this point in its path the flame has been continuously receiving more heat by combustion than it has been losing by radiation.

It is important to note that the flame did not begin to cool fairly early in its path and therefore radiated heat to the coil beneath it, the tubes above it and to the cooler parts of the flame in front of the furnace. Evidently the coal burns on approaching the center, raising the temperature; then the bulk of the flame passes upward rapidly, leaving a comparatively feeble flame over the back of the coil, which keeps the flame comparatively cool.

By means of thermocouples inserted in the staybolt holes in the bottom row it was found that the approximate temperatures of the gas at this point between the tubes of the first pass were as follows: 1 ft. from the front header, 1847 deg. F.; 4 ft. from the front header 1789 deg. F. and 1 ft. from the baffle 1685 deg. F. These temperatures are lower than the true temperatures of the gas because the thermocouples were subjected to the cooling effect of the surrounding tubes.

It was observed that as long as molten ash moves slowly over the surface of the furnace lining it does not penetrate the brick nor wash it away. It does not penetrate and wash away the brick unless it is liquid and the brick is at the temperature of the running slag. The ash from Illinois

coal becomes fluid at 2300 deg. F., therefore the average furnace temperature cannot be kept much above 2300 deg. F. if erosion is to be avoided. Higher furnace temperatures can be maintained by building hollow furnace walls and then drawing most of the air for combustion through the space between the inner and outer section of the walls.

Three other ways are available to keep furnace temperatures down: (1) large amount of excess air, (2) expose a large amount of boiler surface to radiation and (3) place a water screen at the bottom of the furnace. The bottom of the furnace may be cooled by the admission of some air through the cleanout doors.

When a mixture of powdered coal and air enters a furnace it is heated by radiation and conduction from the flame and the coal is raised to its ignition temperature. The speed of flame propagation through this mixture depends on the ratio of coal to air and if this speed is to be kept as high as possible, the mixture must contain con-

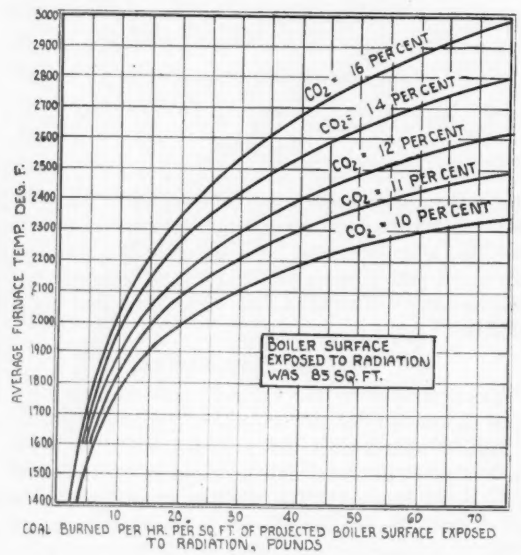


FIG. 6. AVERAGE TEMPERATURES OF THE PRODUCTS OF COMBUSTION

siderably less air than is required to burn it completely. Accordingly, to keep the rate of flame propagation high it is necessary that only a part of the air for combustion be admitted with the coal at the burners and the remainder be admitted later. This device has the additional advantage of facilitating the mixing of the particles of coal, combustible gases and air more thoroughly than the admission of all the air with the coal. It is carried out in this furnace by admitting first of all, through the central burner pipe, equal masses of coal and air, with a downward velocity of 50 to 60 ft. per sec. On the outside of the nozzles an additional mass of air, equal to twice that of the coal, enters downward at about 10 ft. per sec. Thus the relative velocity of these streams is about 40 to 50 ft. per sec. The remaining air, with about eight times that of the mass of coal, passes horizontally through the front wall openings at a velocity of 10 to 20 ft. per sec. and impinges on the flame. Thus the final supply of air moves in a direction nearly at right angles to that of the downward stream of coal and surrounding gases and mixes with it rapidly.

Another factor that assists combustion is the weight of the coal, for its weight causes it to move downward at a velocity, relative to the gases surrounding it, which is approximately proportional to the mean linear size of the particle of coal and to the square root of its density. Thus the larger particles of coal fall with a greater velocity, rise with a smaller velocity and rub against the surrounding gas at a greater rate than the small particles of the same density. This causes the larger particles to burn more rapidly. The necessity for thoroughly agitating the mixture of coal and air becomes clear when one realizes that coal requires about 10,000 times its own volume of air at atmospheric temperature to form about 60,000 times its own volume of gas at furnace temperature, so that if a particle of coal were to enter a furnace in a sphere of air, at ordinary temperature, just large enough for complete combustion of the particle, this sphere of air would have a radius 20 times the radius of the particle. Obviously, unless this mixture of coal and air remained in the furnace a considerable time or the coal particle moved relatively to the air, the particle could not burn completely because the bulk of the air for its combustion must come from the outer part of the sphere.

Rotary Versus Centrifugal Pumps

By Wm. F. Traudt

ENGINEERS IN INDUSTRIAL power plants are often confronted with the problem of deciding whether rotary or centrifugal pumps are to be used for a particular service. This problem is not difficult of prompt and satisfactory solution if a few fundamental points are brought to bear on the subject.

Fluids like water, calcium chloride or sodium chloride brine, caustic soda, vinegar, etc., can be best handled with a centrifugal pump, the type depending upon the gallons per minute to be pumped, the head and means of driving. The reason why one should select a centrifugal and not a rotary pump in these cases is because such liquids as referred to above have practically no lubricating qualities, therefore causing a rotary pump to wear rapidly.

Rotary pumps wear more rapidly, due to the fact that such pumps have moving parts, the surfaces of which come in metallic contact with one another and when not provided with a satisfactory lubricant, cause rapid wear. The wear is particularly severe when handling refrigerating brine or water, and is increased when pumping against pressure. Also, the faster the rotary pump operates, the greater the wear.

Rotary pumps are built in many forms (too numerous to describe here) but all require some form of rotating element or elements; such as two gears opposing each other, or gears within a gear, or several forms of cams, vanes, valves, buckets or blades sliding through slotted rotors. There always is a type or design which is better adapted for one kind of service than another. Some are made to run slow for viscous fluids and some fast for lighter fluids but as the working elements cannot receive any lubrication within the pump other than the fluids being pumped, it is obvious that wear will be rapid and excessive when applying a rotary pump to water or brine service.

Since one would not think of using salt brine or vinegar in the transmission of an automobile, as a lubricant, why should one expect satisfactory service from any form of gear type rotary pump?

Centrifugal pumps, however, are suited for such service

because the impeller is balanced and does not require to be in metallic contact with the casing. In fact, all revolving elements are clear from the casing with the possible exception of the shaft in the stuffing-box, which can, in a measure be protected. The rotary pump is satisfactory on materials like cotton seed oil, lard, compound, and in fact all oils even such as cold cylinder stock. One must be mindful, however, that the more viscous the oil the slower the pump must operate. In other words, the speed of a rotary pump or what amounts to the same thing, its capacity must be in a measure synchronized with the flowing qualities of the viscous fluid. The rotary pump is also satisfactory on fluids like asphalt, tar, molasses, glucose, white lead, varnish chocolate, paint, etc. It must, however, be remembered that a 2-in. pipe might carry cold glucose at the rate of 5 gal. per min., while a light motor oil could be carried at from 75—100 gal. per min. Thus a 2-in. rotary pump might have a capacity of 5 or 100 gal. per minute, depending upon the viscosity of the fluid. The revolution of the pump must be adjusted to the viscosity.

There are many types and designs of pumps, whether plunger, rotary or centrifugal; no one type is suitable for every purpose. It requires thought and care to prevent the misapplication of pumps, and the manufacturers suggestion should be sought when in doubt. There are some people, however, who in recent years have come to look on the rotary pump as a "Universal Pump," therefore, a substitute for every other type. Such a conclusion is not only wrong but frequently leads to unfortunate and expensive experience. The object of this article is to be of assistance to those who must decide on pumping equipment. There is a large field of usefulness for the rotary type of pump but when a fluid has no lubricating properties, rapid wear is to be expected.

Engineering at the Equator

By M. M. Brown

MEN experienced in that line, will agree with me that the life of the erecting engineer is not all sugar. When he finishes one job, he never knows where he will be sent to next. He may, on the completion of the work, be ordered to another, farther away, without having a chance to go home to his family, even for an hour. Then, sometimes his employer fails to give him definite instructions and if, in an emergency, he happens to make a wrong guess, it is all off with him. Occasionally, through somebody's blunder, the wrong material is sent. If one is a long way from his base of supplies, it causes vexatious delays and considerable explaining to the head office.

Joe Creighton and I were the only two men working from the New York office of a Western firm of engine builders. Joe said that he was slated for a South American job and had bid me goodbye that afternoon, so I was much surprised to see him blow into my room at 11 o'clock that night in an agitated condition.

"You have got to go to British Guiana in my place," he said. "My wife was taken to the hospital tonight. I have been to the boss' house in Mount Vernon. He ordered me to tell you to go. The ship lies at the foot of West 21st St. and sails at four in the morning."

"But I can't go so soon," I said. "I have to have instructions, and expense money."

"Here are your instructions and money," and he threw a long envelope and a roll of bills on the table. "Count it, and give me a receipt," he said.

So at four o'clock, I stepped aboard the tramp steamer "Anemone," bound out. On the trip, I examined my "instructions," which proved to be only a copy of the contract. Arriving at the port of destination, I learned that no arrangements had been made for transshipping the machinery to the town of Panile by lighter. As the scows there were small, I was obliged to hire two of them, taking the two halves of the flywheel, both cylinders, frame, shaft and part of the tools on one scow and the receiver, condenser, piping, tools and rigging on the other. A tug took us up the river to the site of the plant.

At this point, was an old, dilapidated wharf that I would not trust with my own weight, to say nothing of 6 T. Our manager had informed Joe that he could obtain all the help he needed at the plant. There was an electrician from Demarara working there, installing two alternating current generators, which were to be operated by our engine. These machines were to be run from a line shaft in conjunction with other generators which furnished power and lights to the town, and for some mines near by.

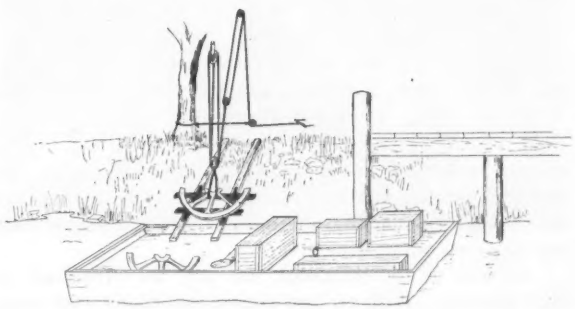


FIG. 1. NO CHANCES WERE TAKEN WITH A WEAK LOOKING WHARF BUT THE SKID AND TACKLE METHOD WAS ENTIRELY SUCCESSFUL

Our 250-hp. cross-compound Corliss condensing engine was expected to take most of the load and relieve the old-fashioned English engine then in use. The electrician told me that I should get no help or information from the chief, as he was disgruntled because the company had bought an American engine and he had lost the commission promised him by an English agent. I hired some laborers in the town and started the excavation for the foundation and to unload the scows.

On the bank near the wharf grew a large tree, which we used for a derrick. A scow was lashed to the bank, and two mahogany logs were used for skids. With a luff-tackle on the hoisting falls and a mule, even the heaviest pieces came up easily. When the excavating was finished, a concrete base 1 in. thick was laid. No broken stone was obtainable in the town, so rubble stone, broken up with a sledge-hammer was used. The ratio of the mixture was one part of cement, two of sand and four of the rubble. It made a fair base.

There was a sawmill nearby where I was able to get lumber and blocking. I made a template from a blueprint

which I found in the toolchest. I got my lines from the shafting the engine was supposed to run and set up the template accordingly, and then hired four bricklayers.

In the meantime, I was having some little trouble with my help. They would lay off at times when they were needed, and get "sassy" when called down about it. All this, I was told, was instigated by the chief, who was afraid I was going to take his job. As it happened, I was able to do a good turn for the boss stevedore who loaded my ma-

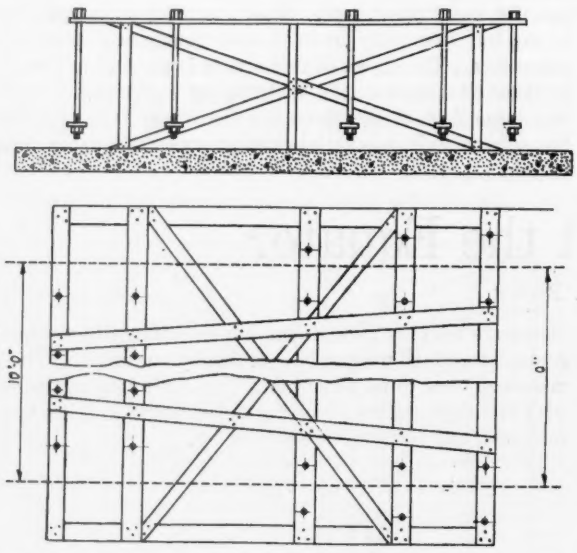


FIG. 2. ELEVATION AND PLAN OF THE TEMPLATE FOR THE ENGINE FOUNDATION

chinery onto the scows, a big, husky Jamaican negro. He had said that he was a rigger and would like to work for me. I sent for him and he came at once, and soon showed my lazy crew where they got off.

As soon as the brickwork was dry, we were ready to start erecting. With my new rigger, everything went along like clockwork. As fast as one piece was bolted up, another was ready. Outside of some pipe-cutting for the suction to

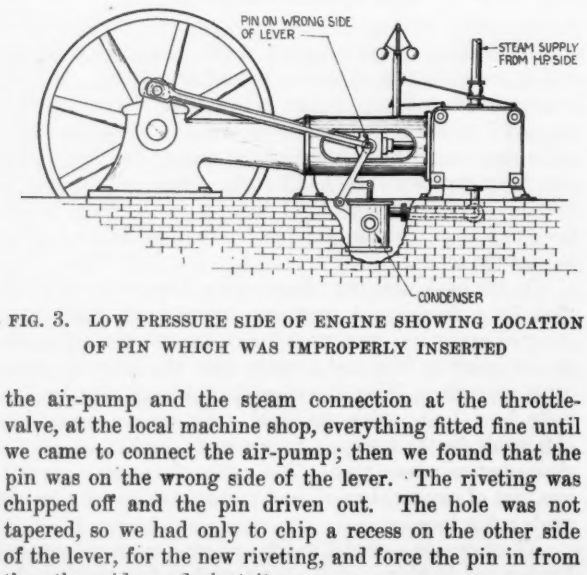


FIG. 3. LOW PRESSURE SIDE OF ENGINE SHOWING LOCATION OF PIN WHICH WAS IMPROPERLY INSERTED

the air-pump and the steam connection at the throttle-valve, at the local machine shop, everything fitted fine until we came to connect the air-pump; then we found that the pin was on the wrong side of the lever. The riveting was chipped off and the pin driven out. The hole was not tapered, so we had only to chip a recess on the other side of the lever, for the new riveting, and force the pin in from the other side, and rivet it up.

All this work had taken seven weeks, and I had received one cable from the home office, asking "how I was getting along." After putting on the main belt, and running one hour, I cabled O.K. to the office in New York. The contract called for a 15 days' run before turning the engine over to the company and getting my release.

Even the chief admitted that the engine ran better than the old English rattletrap he had been running, and the people of the town and at the mines were delighted with the new, steady lights. But I wasn't sorry to take passage for little old New York. In 4 deg. north of the equator, you will perspire all day and sweat all night, and they certainly have a monopoly on mosquitoes and every other kind of bug that ever was hatched. All the natives are addicted to laziness which is extremely aggravating to a northern man.

Pipe Bending

WHEN IT IS necessary to bend pipes by hand without the use of special tools, this can be done by the following method: Completely fill the pipe with dry sand and block or cap the ends so that the filling will be retained. Heat the part to be bent; the heating should be restricted to this part and overheating should be avoided. It is usually necessary to heat two or three times when making a bend of small radius, so that nothing is gained by heating to a high temperature. Clamp the pipe in a vise as close to the location of the bend as possible without gripping the heated part. Then cool the outside of the curve by water, so that the inside, being hot and plastic, is compressed as the bend is made; by forcing the bend to take place on the inside, the pipe walls are better supported by the filling material, because the cubic contents are slightly reduced by the compression; if the outside of the curve were allowed to stretch, the cubic contents would be slightly increased, which would result in a lack of support for the interior of the pipe. The use of water also plays an important part in the formation of the curve, the pipe being cooled wherever the required curvature has been obtained. The use of water for cooling the outside of the curve can usually be dispensed with when the radius exceeds 15 times the pipe diameter.

When bending butt-welded iron pipe, the seams should be on the inside and outside of the curve and not on the sides, to lessen the danger of cracking. When heating must be avoided on account of the finish, or for other reasons, a filling is ordinarily used that can be melted at a low temperature, such as rosin for copper and brass, or a metal alloy having a low melting point, for small iron and steel pipes. Brass and copper pipe should be annealed before bending.

IN TESTS recently made on the Benson super high-pressure generator, which is designed to make steam without ebullition at 3250 lb. and throttle to 1500 lb., then superheat it, it was found that the superheat was, on the average, 865 deg. but at times it rose to 910 deg. The temperature of the flue gases at the foot of the stack at no time exceeded 110 deg. F. and the casing of the generator was just pleasantly warm to the hand, a most remarkable condition for a boiler generating steam at 3250 lb. and 725 deg. The results are reported in Engineering of London by W. A. Johnston, chief engineer of the Benson Engineering Co., Ltd.

Cahokia

(Continued from page 371.)

Two separate chemical tanks are provided, one containing iron sulphate and the other calcium hydrate. These two chemicals, it will be noted, are introduced into the water in separate dilution tanks, although the total output of both dilution tanks come together in what is termed the riffle trough. From the riffle trough the semi-treated water passes through a series of settling tanks and finally to the semi-treated water pumps. Cooling water returns from bearings, etc., enter the third settling tanks.

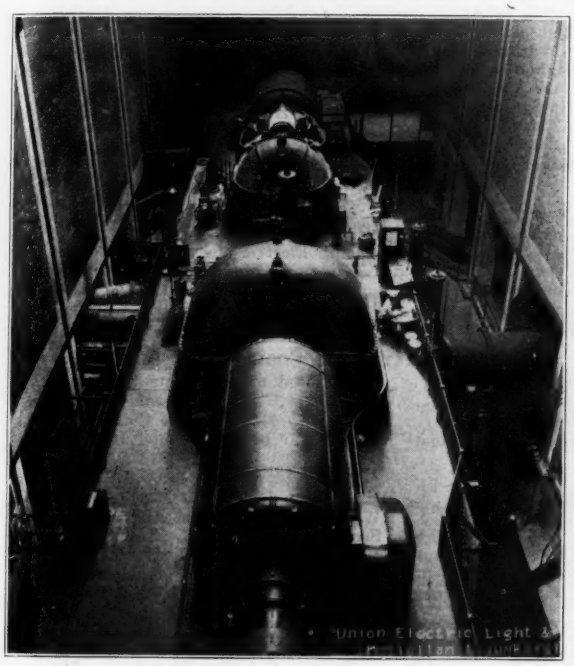


FIG. 8. LOOKING OVER THE TURBINE ROOM OF THE FIRST SECTION

Water that is to be still further treated passes from the semi-treating system to the secondary system at weir box No. 2 and follows through in the same manner as in the primary system. In this system the water is treated with Barium hydrate which acts on the sulphates contained in the water. The iron sulphate and calcium hydrate used in the primary system acts on the carbonates and hastens precipitation.

After having been treated in the secondary treating system the water passes through filters into four large concrete storage tanks.

Water for boiler feed purposes is taken from the treated water storage tanks and is delivered to low pressure, two effect Lillie evaporators having a capacity of 10,000 lb. per hr.

Deaeration is effected in an open heater of the reboiler type having a capacity of 720,000 lb. per hr. This heater is heated by exhaust steam from the house turbines.

From the foregoing it will be evident that the water treating equipment at Cahokia is the last word in refinement and there may be some doubts in the minds of readers as to whether the advantages obtained by the use of this elaborate system justify the investment.

In considering this phase of the question, it must be remembered that in central station practice, all possibility of shut down must be avoided. If by means of a water treating system such as this an absolutely pure, non-corrosive boiler water can be secured, it is evident that the savings effected due to the decrease in boiler maintenance, will go a long way towards justifying the expense of the treating system.

The Turbine Room

If any one part of Cahokia is more impressive than another, in our opinion, this is the turbine room. Here the huge turbo-generators whirring away quietly impart an atmosphere of dignity that is lacking in the more spectacular aspects of the boiler room. The spacious airy room, the symmetrical arrangement of equipment presents an unusually attractive appearance. The turbine room at Cahokia, as in all modern power stations, occupies only a relatively small portion of the total volume of the station. This tendency in plant design has resulted not only from

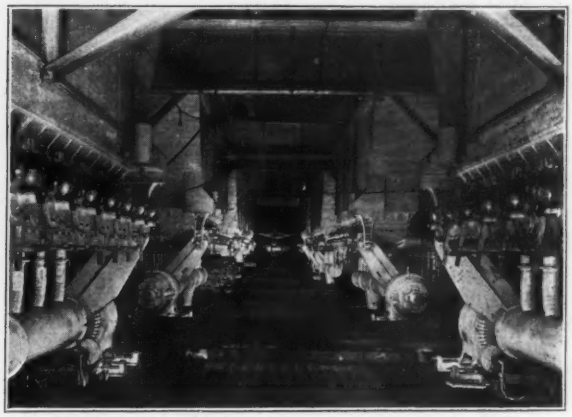


FIG. 9. BOILER ROOM AISLE AT FEEDER LEVEL

the decreased size of generator units per kilowatt capacity but also because of the increased height of modern boiler settings.

When the ultimate station is finally completed the turbine room will be some 650 ft. in length. The generating units are placed end to end on the long narrow platform formed by the turbine pedestals or foundation. This construction permits of easy access to the condensing equipment beneath and also insures an adequate supply of natural illumination to the condenser floor.

Two of the eight generators that will stretch down this vast turbine room are already at work. One of these is a General Electric Curtis 17-stage machine with a rating of 35,000 kv.a and the other is a Westinghouse, semi-double flow unit also with a rating of 35,000 kv.a. These machines are both equipped with direct connected exciters, although an auxiliary exciter is also provided.

Electrical characteristics of both units are the same, being 13,800 v., 3-phase, 60-cycle, 1800 r.p.m. Steam is supplied to the throttles of the turbines at 300-lb. pressure and at a total temperature of 690 deg. F.

Air from the generator windings is cooled in a closed circuit by means of condensate in Griscom-Russell Co. surface air coolers. In this manner the air is supplied to the machines at the correct temperature and, at the same time, all the available heat from the generator windings is trans-

Principal Equipment in the Cahokia Station

Raw Coal Handling Equipment

Track scale ..... Buffalo Scale Co.
Car dumper ..... Link-Belt Co. ..... 90 T.
Conveyors ..... Link-Belt Co. ..... 300 T. per hr.
Crushers ..... Bradford Breaker ..... 400 T. per hr.
American Pulverizer Co. 60 T. per hr.
Magneto Separators ..... Ding ..... 2—24 in. by 38 in.
Cranes ..... Brownhoist, locomotive type.
American Hoist and Derrick Co.
American Saddle Tank.

Pulverized Coal Handling Equipment

Platform scales .... Howe Scale Co. ..... 45 T.
Transport systems. Quigley compressed air system. .94 T. per hr.

Drying, Pulverizing and Combustion Equipment

Method of firing ..... Lopulco.
Dryers ..... Wood ..... 6.5 T. per hr. each
Fans ..... B. F. Sturtevant ..... 60,000 c.f.m.
Pulverizers ..... Raymond Bros. (Impact) .....
..... 6 T. per hr. each
..... 15 T. per hr.
Feeders and burners .. Lopulco ..... 10 per boiler
Primary air fans .... B. F. Sturtevant Co. ..... 20,000 c.f.m.
Control equipment ... Bailey Meter Co.
Uptakes and flues .... Connery and Co.

Furnaces

Refractories ..... Laclede Christy Clay Products Co.
Evans and Howard Fire Brick Co.
Walsh Fire Clay Products Co.
Insulating brick ..... Sil-o-cel
Suspended arches ..... M. H. Detrick Co.
Liptak Fire Brick Arch Co.
Brickwork erected by .... D. Seeger
Ash gates ..... Allen-Sherman-Hoff Co.

Ash Handling Equipment

Make of system ..... Allen-Sherman-Hoff Co.
Dredge pumps ..... Morris Machine Works

Stacks

Tile-concrete type ..... Made by Wiederholdt Construction Co.

Water Supply

Treating system ..... Graver Corporation cold process ...
..... 600 g.p.m.
Refrigeration system for drinking water ..... R. H. Tart & Sons, Inc.
Filters ..... New York Continental Jewell Filtration Co.
Evaporators ..... Sugar Apparatus Mfg. Co. .....
..... 10,000 lb. per hr.
Deaerating equipment ... H. S. B. W.-Cochrane Corp. .....
..... 720,000 lb. per hr.

Boiler Feed Pumps and Excess Pressure Regulators

Boiler feed pumps ..... Allis-Chalmers .... 6 stage 750 g.p.m.
B. F. pump drive ..... 3 by General Electric Co. motors ..
..... 300 hp. induction.
1 by Terry turbine ..... 300 hp.
Excess pressure regulators ..... Ruggles-Klingemann
Fisher Governor Co.
Feed water heaters ..... Alberger Pump and Condenser Co.
Oil and water tanks ... Hamler Boiler and Tank Co.

Boilers and Superheaters

Boilers ..... Babcock & Wilcox Co. ..... 1801 hp.
Superheaters ..... B. & W. Alert type ..... 4070 sq. ft.
Soot blowers ..... Diamond Power Specialty Co. .....
..... 18 per boiler
Feed water regulators ... Copes ..... 2 per boiler

Piping, Valves and Covering

High pressure steam, boiler feed and boiler blowoff piping and fittings by Midwest Piping and Supply Co.
Low pressure steam piping and fittings by Steere Engineering Co.
Circulating water piping by Joubert and Goslin Machine & Foundry Co.
Heat insulation by Philip Carey Mfg. Co. High temperature and 85 per cent Carbonate of Magnesia.
Boiler non-return and high-pressure steam globe valves by Edward Valve and Mfg. Co.
High-pressure steam gate valves by Crane Co.
Motor operating mechanisms for high pressure steam gate valves by Payne Dean Limited.
High-pressure boiler feed-gate and check valves by Chapman Valve Mfg. Co.
High-pressure boiler feed-globe valves by Lunkenheimer Co.
Low-pressure steam and water valves by Nelson Valve Co. and others.
Circulating water hydraulically operated gate valves by Kennedy Valve Mfg. Co.
Atmospheric relief valves by Atwood and Morrill.
Yarway seatless blowoff valves in series with Lunkenheimer gate valves.
High-pressure steam joints are of the Sargol type 800 lb. hydraulic standard.
High-pressure boiler feed and low-pressure steam joints are of the Van Stone type.
Piping systems erected by McClellan and Junkersfeld, Inc.

Prime Movers

Make ..... General Electric Co. ..... 30,000 kw. Curtis
Westinghouse Electric & Mfg. Co. .... 30,000 kw.
Semi-double flow

House Turbines

Make ..... Westinghouse Electric and Manufacturing Co.
Type ..... Horizontal, non-condensing
Number ..... Installed 2; Ultimate 2
Rating ..... 2000 kw.
Electrical characteristics ..... 2300 v. 3-phase 60 cycles

Generator Air Cooling System

System ..... Closed system with surface coolers
Air coolers ..... Griscom-Russell Co.
Heat exchangers ..... Whitlock Coil Pipe Co.
Generator air ducts ..... by John Nooter Iron Works

Condensers

Make ..... Worthington Pump and Machinery Corp.
Tubes ..... Wheeler Condenser and Engineering Co.
Scovill Mfg. Co.
Circulating pumps ... Worthington Pump and Machinery Corp.
Cir. pump drives ..... General Electric Co. induction motors
Condensate pumps ..... Worthington Pump & Mach'y Corp.
..... 800 g.p.m.
Condensate pump drive .. Wagner Induction Motors ..... 75 hp.
Dry vacuum pumps ..... Laidlaw-Dunn-Gordon Feather Valve
R. D. V. pump drive .... Wagner Induction Motor ..... 50 hp.

Sluice Gates

Make ..... Coffin Valve Co.
Number ..... 11 Gates, 1 Butterfly Valve

Intake Water Screens

Make ..... Link-Belt Co. .. 5 ft. wide 52 ft. high
Water screen drive ..... 5-hp. motor through Jones speed reducers
Raw water pump screens. Elliott Co. ..... 12 in.

Auxiliary Equipment

Turbine room crane ..... Niles-Bement-Pond Co. ..... 110 T.
at 5 ft. per min.

Air Compressors

Make ..... Sullivan Machinery Co. ..... 760 c.f.m.
100 lb.
Compressor drive ..... Wagner induction motors .... 150 hp.
Aftercoolers ..... Whitlock Coil Pipe Co.
Auxiliary exciter ..... 300 kw. 250 v. 760 r.p.m.
Auxiliary exciter drive .. General Electric Co. Turbine and General Electric Co. Motor

Special Centrifugal Pumps

Raw and semi-treated water pumps ..... Worthington Pump & Machy. Corp.
Sludge pumps ..... Worthington Pump & Machy. Corp.
..... 350 g.p.m.
Make-up pumps ..... Worthington Pump & Machy. Corp.
..... 500 g.p.m.
Sump pumps ..... Yeomans Bros. ..... 500 g.p.m.
Fire pump ..... Dayton-Dowd Co. ..... 750 g.p.m.
Sludge pumps, make-up pumps, sump pumps and fire pumps all driven by Wagner motors

Principal Equipment in the Cahokia Station—Continued

Heating system returns..Nash Engineering Co.
Transformer oil circulat-Worthington Pump & Machy. Corp.
ing pumps.....110 g.p.m.

Test Tanks

Tanks.....Hamler Boiler & Tank Co.
Scales.....Strait Scale Co.....30,000 lb.

Oil Purifying System

Purifiers.....DeLaval.....300 g.p.h.
Circulating and filling pumps.....American Steam Pump Co.

Transformer Oil Coolers

Coolers.....Whitlock Pipe Co.
General Electric Co.
Westinghouse Elec. & Mfg. Co.
Griscom-Russell Co.

Ventilating Fans

Ventilating blower.....American Blower Co....72,000 c.f.m.
Also 2 American Blower Co. fans..
.....1800 c.f.m.

Instruments

Resistance thermometers.....Wilson Maeulen Co.
Recording thermometers and pressure gages.....Foxboro Co.
Steam flow meters.....General Electric Co.
Recording flow meters for boiler feed water.....
.....Simplex Valve & Meter Co.
Boiler meters.....Bailey Meter Co.
Indicating pressure and vacuum gages.....
.....Crosby Steam Gage & Valve Co.
.....Ashton Valve Co.
.....American Schaeffer & Budenberg Mfg. Co.
.....C. J. Tagliabue Mfg. Co.
.....Manning, Maxwell & Moore, Inc.
Mercurial thermometers.....Taylor Instrument Co.

Elevators

Otis elevators in Electrical Bay, Boiler house and in coal tower.

Main Oil Circuit Breakers

Make.....General Electric Co.
Operation...Remote controlled, motor operated at 125 v., d. c.
Rupturing capacity.....38,000 amp. at 13,800 v.

2300-Volt Auxiliary Power Oil Circuit Breakers

Make.....Westinghouse Electric & Mfg. Co.
Operation..Remote controlled, solenoid operated at 125 v., d. c.
Rupturing capacity.....16,000 amp. at 2500 v.

440-Volt Auxiliary Power Oil Circuit Breakers

Make.....Westinghouse Electric & Mfg. Co.
Operation..Remote controlled, solenoid operated at 125 v., d. c.
Rupturing capacity.....15,000 amp. at 440 v.

Motor Generator Sets

Numbers installed	2	2
Service	D. C. Power	Battery Charging
Make	Westinghouse	Westinghouse
Generator—		
Capacity	100 kw.	25 kw.
Voltage	250 v.	125/175 v.
R.p.m.	1160	1160
Winding	Compound	Shunt
Motor—		
Size	150 hp.	35 hp.
Voltage	2300 v.	440 v.
Type	Squirrel Cage	Squirrel Cage

Transformers

Step-up tie feeder transformers—Three transformers, each 3-phase, delta—zig-zag, 12,000 kv.a., 60 cyc., 13,800/33,000 v., forced oil cooled, General Electric Co.
Step-up feeder transformers—Three transformers, each 3-phase, delta—zig-zag, 7500 kv.a., 60 cyc., 13,800/33,000 v., forced oil cooled, General Electric Co.
Station power transformers—Two transformers, each 3-phase, delta-delta, 3000 kv.a., 60 cyc., 13,800/2300 v., self and water-cooled, General Electric Co.
Two three-phase, delta-delta, 750 kv.a., 60 cyc., 2300/440 v., self-cooled oil insulated Westinghouse Electric & Mfg. Co.
Two three-phase, delta-delta, 200 kv.a., 60 cyc., 2300/440 v., self-cooled oil insulated Westinghouse Electric & Mfg. Co.
Station lighting transformers—Two single phase transformers, 150 kv.a., 60 cyc., 2300/220/110 self-cooled, oil insulated Westinghouse Electric & Mfg. Co.

Disconnecting Switches

Operation Remote hand operated from floor below lowest phase
Make.....General Electric Co.
General.....All 2300 and 440 v. disconnects are S. P. S. T.
Operation..... Hook stick
Make.....Electric Power Equipment Corp.

Main Current Transformers

Make.....General Electric Co.

Main Potential Transformers

Make.....General Electric Co.
Type—Oil insulated, with one fuse and current limiting resistor for star connection.

Reactance Coils

Make—General Electric Co. for generators and bus ties; Metropolitan Device Corp. for feeders.
Number installed—Six for generators; three for main bus tie and twenty-four for feeders.

Storage Batteries

Service.....D. C. control and emergency lighting
Number installed..... Two
Make.....The Electric Storage Battery Co.
Capacity.....81 amp. for 8 hr. and 360 amp. for 1 hr.
Voltage.....126 v.

Main Generator and Tie Feeder Control Benchboard

Comprising the following sections: Two 35,300 kv.a. 13,800 v., 60 cyc. generator sections; two sections, each having two 12,000 kv.a. 13,800 v., 60 cyc. station tie feeders and 1 section for 13,800 v. bus tie and neutral ground, 1 bracket section for voltmeter and synchronizing indicators.
Make.....General Electric Co.

Main Generator and Tie Feeder Control Benchboard

Comprising the following sections: Two sections having one 3000 kv.a., 13,800/2300 v. station transformers, and one 5000 kv.a., 13,800 v. feeder; three section having one 5000 kv.a., 13,800 v. feeder, and one 7500 kv.a., 13,800/33,000 v. feeder, and two sections having two 5000 kv.a., 13,800 v. feeders.
Make.....General Electric Co.

Miscellaneous

Wire and cable—General Electric Co., Standard Underground Cable Co., Simplex Wire & Cable Co., Safety Insulated Wire & Cable Co., American Steel & Wire Co., United States Rubber Co., Crannell, Nugent & Kranzer.
Bus copper and ground plates.....Rome Brass & Copper Co.
Bus and cable supports and inserts—Electrical Development & Machine Co.
High tension bushings.....R. Thomas & Sons Co.
Cable clamp insulators.....General Device & Fitting Co.
Trolley wire.....American Copper Products Corp.
Trolley wire supports, turnbuckles, etc.—Electric Service & Supplies Co.
Iron conduit—Western Electric Co., Manhattan Electrical Supply Co.
Fibre conduit and bends.....Johns-Manville Co.
Generator temperature recorders.....General Electric Co.
Telegraph pedestals and indicators.....General Electric Co.
Fire alarm system.....Gamewell Fire Alarm Telephone Co.
Sash motor controls—Cutler-Hammer Co.; number installed, 2.
Kinnear rolling door controls..Westinghouse Magnetic switches.
Lighting cabinets—Frank Adams Electric Co.; number installed, 16.
Sheet steel junction boxes—All-Steel Equipment Co., Columbia Metal Box Co.
Lighting fixtures—Porcelain enameled steel reflectors and marine type fixtures—Benjamin Electric Mfg. Co.; glass reflector fixtures—The Holophane Co.; water column Illuminators—the National Co.; miscellaneous fixtures and fittings—Crouse-Hinds.

ferred to the boiler feed water. The amount of cooling air required by the generators amounts to 80,000 cu. ft. per min. at 104 deg. F. for each machine.

Another thing of interest in connection with the generator cooling air system, is the fire suppression system installed. This consists of an arrangement of receivers containing CO_2 gas at 200-lb. pressure connected so that this gas may be discharged into the ventilating system in case of fire. The CO_2 gas being non-combustible will effectively suppress any fire which may break out.

A secondary system of generator fire protection is also provided in the form of water coils in the end bells of the generators.

The turbo generators are supported on steel and concrete pedestals with the condensers directly below. These pedestals are detached entirely from the rest of the building so that no vibrations may be transmitted from one to the other.

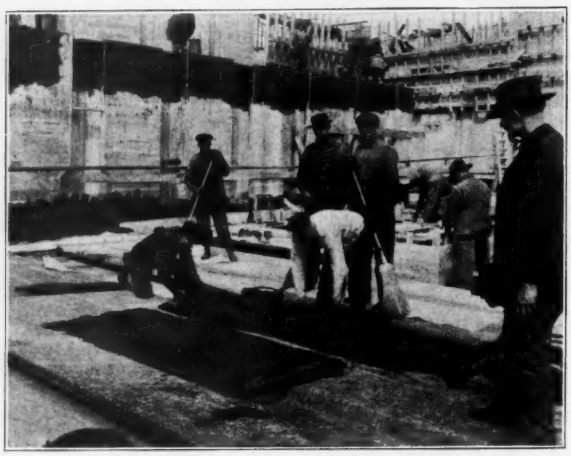


FIG. 10. PUTTING ON THE WATER PROOFING MATERIAL AT CAHOKIA

In mounting these machines, 70-ft. concrete piles were first driven to good gravel bearing strata for a base. On top of these piles, was placed five feet of solid concrete and on top of this was erected 40 ft. of concrete and structural steel upon which the turbines are placed.

Each generator is provided with a two-pass surface condenser having 53,000 sq. ft. of cooling surface. Circulating water is taken directly from the Mississippi through intake openings in the river wall. The intake tunnels do not extend beyond the river wall. The water after passing through bar racks located below low water passes through Link-Belt Co. traveling water screens. These water screens are 5 ft. wide and are 52 ft. between sprocket link centers.

Two 30-in. circulating pumps serve each condenser, two of 27,000 gal. per min. capacity when connected in parallel and of 33,000 gal. per min. each operating alone. These pumps are direct connected to 250-hp., 2300-v., 60-cycle, 3-phase variable speed inductive motors. The circulating water lines are fitted with hydraulically operated gate valves remotè controlled from the operating floor.

Condensate removal is effected by 800-g.p.m., 2-stage centrifugal pumps; air removal by a 33 by 24-in. Laidlaw-Dunn-Gordon, feather valve rotative dry vacuum pump, for each condenser.

Main Steam Piping

Main steam piping is so arranged that eight boilers together with two turbines form a unit. As may be noted from the station plan, Fig. 4 each set of two boilers is connected to one header, running parallel to the turbine room. Ordinarily four boilers on one side of the building serve the turbine on the same side of the building but the main boiler room header permits the feeding of steam to either of the two turbines in the section.

Main steam lines connecting each pair of boilers are fitted with motor operated high pressure gate valves, to the header controlled from the boiler and turbine room. The station contains approximately 1000 lineal feet of superheated steam pipes. These lines are insulated with one inch of Carey Hi Temp and three inches of Carey 85 per cent magnesia. With the 85 per cent magnesia alone, the covering would not have the necessary lasting qualities but with the addition of the inner protective layer, the pipe insulation can easily withstand temperatures of as much as 1000 deg. without deterioration.

Auxiliaries

All auxiliaries are electrically driven except for one boiler feed pump and one duplex exciter. The direct current fuel feed motors for the pulverized coal burners in the boiler room are supplied with current from duplicate motor generator sets.

Normally all electrically driven auxiliaries are driven from the main generators through house transformers but when it is deemed advisable, or when the heat balance of the station demands, they are driven from the house turbines. These house turbines, of which there are two, are Westinghouse, non-condensing machines rated at 2500 kv.a., 2300 v., 3-phase, 60 cycles. They are supplied with steam at 300-lb. pressure and exhaust at 18-lb. absolute. The generators are provided with saturated core reactors to prevent overloading.

All large motors driving auxiliaries are supplied with current at 2300 v. All motors up to 150 hp. were supplied by the Wagner Electric Mfg. Co.

Electrical Features

In the design of the electrical features of Cahokia, reliability and safety of operation were the principal factors to be considered.

Current is generated at 13,800 v. and is stepped up for transmissive and for tie line purposes, to 33,000 v. Three tie feeder transformers are installed. These are each 3-phase, delta-zig-zag. 12,000-kv.a. 60-cycle 13,800/33,000-v., forced oil-cooled General Electric Co. units.

Step up feeder transformers are similar to the tie line transformers insofar as voltage and connections are concerned but are rated at 7500 kv.a. instead. Oil used in these transformers is cooled in external coolers using condensate as the cooling medium.

Station transformers consist of two 13,000/2300-v. units, for the large motor driven auxiliaries, two 2300/440-v. units for small motors, and four single phase units 2300/220/100 v. for station lighting purposes.

Auxiliary motors are controlled from the individual machine and from a group control switchboard located on the main generator floor level by the electrical bay.

Main oil circuit breakes are rated as follows: six 2000-amp. for generators and line ties; four 1200-amp. for generator neutrals and thirty-four 800-amp. units for feeder bus selectors. These are all of General Electric Co.

make, being the type F.H.D.-17 single-pole, for isolated phase arrangement. They are remote controlled, motor operated and have a rupturing capacity of 38,000 amp. at 13,800 v. All switches are mounted in concrete compartments with a separate floor for each phase. The vertical isolated phase arrangement is used with the operating mechanism floor below the circuit breaker floor.

All disconnecting switches for 13,800-v. operation are of the single-pole, single-throw type and are located in the same compartment as the oil circuit breakers. They are remote hand operated from the floor below the lowest phase.

Operation

This station was put into service on Oct. 15, 1923, or about 13 months after the first pile was driven, because of the urgent demand for additional power.

Since then one turbo-generator has been continuously in commercial service, and the other intermittently from Nov. 30 to Feb. 20, and continuously since the latter date.

Seven boilers were put into steaming service on various dates from Oct. 2 to Jan. 10, and the eighth boiler on Feb. 15, and the various elements of coal handling and coal preparation as needed in advance of boilers and furnaces.

The total station economy from coal as received on car dump has been as follows:

	B.t.u. per Kw.-Hr. Gross	Net	Max. Load Kw.	Capacity Factor	Net Output Kw.-Hr.
Jan.... (31 days)	17,922	19,310	40,000	30.3	13,503,200
Feb.... (29 days)	17,579	18,649	45,000	36.3	15,175,900
Mar.... (15 days)	17,339	18,360	45,000	47.0	10,145,400

The foregoing is exclusive of economizers or air preheaters, none having been installed, as the station was designed to burn low grade coal averaging $2.50 per ton. The station has not yet reached its permanent operating load, as indicated by the maximum load and the capacity factor and output given above.

No official or acceptance tests on principal equipment have so far been made except on the No. 1 turbo-generator, with the following results:

	Water Rate, Pounds per Kw.-hr. corrected for 300-lb. Gage and 250° F. Superheat at Throttle.		
Load Kw:	Vacuum ½-in. Abs.	Vacuum ¾-in. Abs.	Vacuum 1-in. Abs.
30,000	9.42	9.45	9.56
23,000	9.57	9.64	9.80
15,000	9.97	10.20	10.41
10,000	10.54	10.90	11.3

Temperature of the flue gases to driers has been varied from 200 to 380 deg. F. for trial and observation, but the average has been increased from time to time, and was 300 deg. F. during the first 15 days of March. The coal used is of a character that catches fire occasionally in ordinary raw coal bunkers. Since the first drier was put into service coal has caught fire twice in drier No. 4 to an extent requiring repairs the first at cost of about $1,400, and the second about $100. There were no other fires that required repairs. There have been 12 smaller so-called fires requiring no repairs and extinguished readily with steam permanently piped with relief for that purpose to the driers, most of them occurring when the driers were out of service and full of warm coal. Such other hot spots as were found occasionally in driers or hoppers below were not sufficient to warrant turning on the steam.

The installation of gates between bunkers and driers, the replacement of butterfly dampers with sliding gas tight dampers, and some improvements inside the driers and ducts will make it possible to reduce greatly the number of fires and more quickly to isolate and extinguish fires should any occur.

There have been six fires due to spontaneous combustion at times of low barometric pressure in about six months in the eight pulverizing coal bins which were located directly under the open vent pipes. They were easily put out by closing the bins and allowing the CO_2 gas generated in the bin to smother the fires. The vent pipes have since been equipped with light weight check valves which relieve the bin of excess pressure and at the same time prevent the entrance of air.

Station records indicate that at 190 per cent rating furnace operation has been adjusted to give 15 to 16 per cent CO_2 without slagging in the furnace with exit gas temperature of 450 deg. leaving the boiler. No repairs have been found necessary on the boiler furnaces or water screen, and the last inspections indicate no distress in any part.

After about five months of preliminary testing, operating and research, designs have been approved and contracts placed for Unit No. 3 fuel preparation including driers, transport and combustion equipment to substantially duplicate that on Units 1 and 2 on which the experience obtained has been embodied as stated above.

Conclusion

Design and construction of the Cahokia Station was carried out by McClellan & Junkersfeld, Inc., Engineers and Constructors, New York and St. Louis, under authorizations of Mr. Louis H. Egan, President Union Electric Light & Power Co., St. Louis, Mo., and with the collaboration of his technical assistant, Mr. H. W. Fales, Chief Electrical Engineer, and Mr. E. H. Tenny, Chief Engineer of Power Plants.

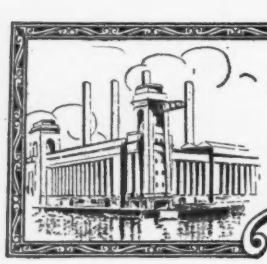
The station is built to carry the domestic, industrial and railway load of the City of St. Louis, Missouri, East St. Louis and surrounding territory.

As is apparent from the foregoing description, this station embodies the best that modern power plant practice has to offer today and has every facility for insuring continuity in the delivery of electrical energy.

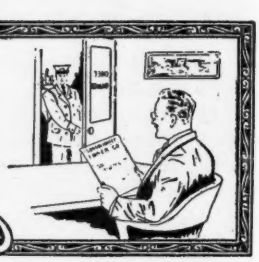
In concluding this description we wish to acknowledge our indebtedness to McClelland & Junkersfeld, Inc., the engineers and constructors, for information given and privileges extended which made the preparation of this article possible.

"Out of sight, out of mind," applies in power plants as well as elsewhere. Consider the engine piston rings. In the small plant where the indicator is not used and the parts in sight look O. K. and carry on all right, the hidden piston rings may be greatly neglected. Remembering that high-speed engines are often run almost continuously every day, it would be little enough if the rings were examined at least once a year and the sharp edges removed with the proper tools or a smooth file.

After a year's run, snap rings will often be found to have a loose fit. One remedy is to expand them by peening but this is not the simple, easy job some writers would lead us to believe.

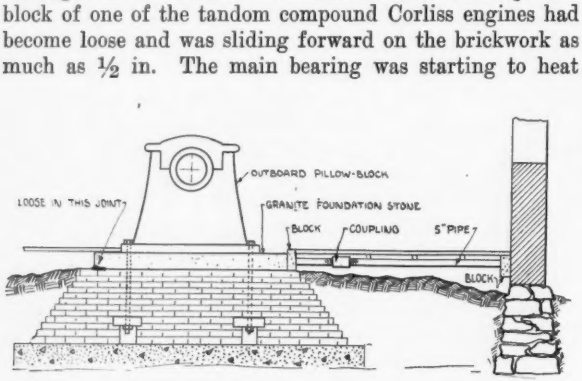


LETTERS DIRECT FROM THE PLANT



Securing Loose Foundation Stone

ONE MORNING, the night engineer reported that during the night the foundation stone under the out-board pillow-block of one of the tandom compound Corliss engines had become loose and was sliding forward on the brickwork as much as ½ in. The main bearing was starting to heat



LOOSE FOUNDATION STONE IS SECURED BY A STRUT FROM THE BUILDING WALL

and he was obliged to shut the engine down. It appeared that the stone moved forward until it was held by the side-pressure on the bolts in the brickwork. Tightening the nuts on the bolts would not cure the trouble. Examination of the fragments of the cement under the stone showed too great a proportion of sand in the mixture.

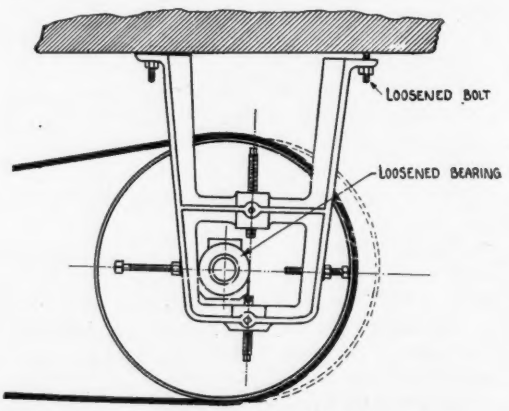
There were no facilities, nor was there time to remove the pillow-block and reset the stone. The front end of the stone was 11 ft. from the building wall. Two pieces of 5-in. extra heavy steel pipe were screwed into a coupling, and adjusted between the stone and the building wall. By unscrewing the pipe from the coupling the stone was pushed back to its original position. After being assured of the proper alinement of the shaft, a long piece of thin steel was used to loosen the old cement under the stone, after which, it was blown out with compressed air. A dam of boards and fire-clay was then constructed all around the stone and 200 lb. of sulphur was melted and poured in the joint. There was no way of knowing how much of the sulphur would run down the bolt-holes but that did not matter as long as it did not run out at the bottom; however, a few pounds of sulphur were left after the joint was full. The chief would not trust the sulphur alone and wished to have the stone braced from the wall, permanently but it was feared that that would cause vibration of the building. The engine was run a few days with the pipe brace but no vibration was apparent. Then a mold of boards was fitted between the stone and wall, and tamped full of concrete, reinforced with pieces of small pipe. The stone has never moved since and is as firm as any other part of the foundation.

Utica, N. Y. M. M. BROWN.

Handy Shaft Hanger Kink*

MOST MILLWRIGHTS agree that it is bad practice to run a large belt onto a pulley by first forcing one of the edges to catch and then running the belt on either by hand or by power. This practice is likely to cause the belt to stretch more on one side than on the other. The belt is thereby permanently injured.

To avoid this condition we are often glibly told to make leather belts endless while they are on the pulleys by means of belt clamps, etc., but that method may not always be practical and sometimes it is impossible, particularly if the



METHOD OF MOVING PULLEY TO PUT ON A BELT

belt has already been made endless by the manufacturers, as is often the case.

Where conditions allow it a good method for putting large belts onto the pulleys so as not to injure them is to loosen the adjusting screws on the hangers as shown in the accompanying sketch. This permits the shaft to move over a considerable distance, temporarily shortening the distance between shaft centers. Sometimes the shaft may be moved inward 2 in. or more, thus making it possible to put the belt on easily. Shortening the center distance 2 in. virtually adds 4 in. to the belt length. To assist further, one of the hanger bolts for bolting the hanger to the overhead beam may be loosened so as to allow the hanger to swing inward. Where patented overhead beams are employed, it is sometimes possible to slide the entire hanger forward without touching the adjusting screws. All of these methods are possible, yet they are seldom used because they are not thought of.

After the belt is on the pulleys, bring the hanger back to its normal position. This is a simple thing to do by turning the nuts where the first and second methods mentioned are employed. The original position of the hanger should always be marked before moving to avoid tedious

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realining. Turn the bearing adjusting screws back to their original positions. These positions are easily found because the screw on the opposite side and the top screw need not be moved at all.

In the sketch, which is drawn slightly exaggerated to emphasize these points, the cross lines indicate where the center of the shaft will be after the beam bolt is retightened and after the adjusting screws are back to their original positions. The dotted curved lines show where the pulley rim will be after everything is retightened and back to the normal position.

To be sure, this method is not always practical where there are belts running in both directions as on a common line shaft but where it can be employed it is well worth while. It is a quick and simple method and the saving effected in large expensive belts surely makes it worth remembering and putting into practice.

Newark, N. J. W. F. SCHAPHORST.

Reason for Fouled Sight-Feed Glasses

So MUCH advice has been given to operators in regard to the methods to use to prevent sight-feed glasses on lubricators becoming oil fouled that it requires courage to offer another article upon the same subject. Wires suspended from the top to catch the oil drop, wires attached to the bottom to steer the drop, glycerine, soap, salt, placed in the glass to increase the density of the water, and so on, schemes without end have been tried, I think I have read them all.

For about 35 yr. I have worked in and about power plants and my personal opinion is that the main reason that the lubricator sight-feed glasses foul with oil is due to the condition of the nozzle at the bottom of the glass (of course, any glass will foul if the water is permitted to escape and oil is allowed to enter before the glass becomes refilled with water).

There are different ways to remedy this condition but the best plan is to remove the cause. Often the upper part of the nozzle becomes coated with a hard sediment, this roughness has a tendency to hold back the oil drop until it becomes so large that it touches the side of the glass when rising. Every drop that touches leaves a small portion of oil upon the glass until one finally touches hard enough to break the drop. This is the start to a fouled glass.

To remedy this condition, remove the glass, clean the dirt from the nozzle outlet, inside and outside, rubbing it until it has a good polish. After this treatment it will be noted that the drops of oil will be of moderate size when they become detached from the nozzle.

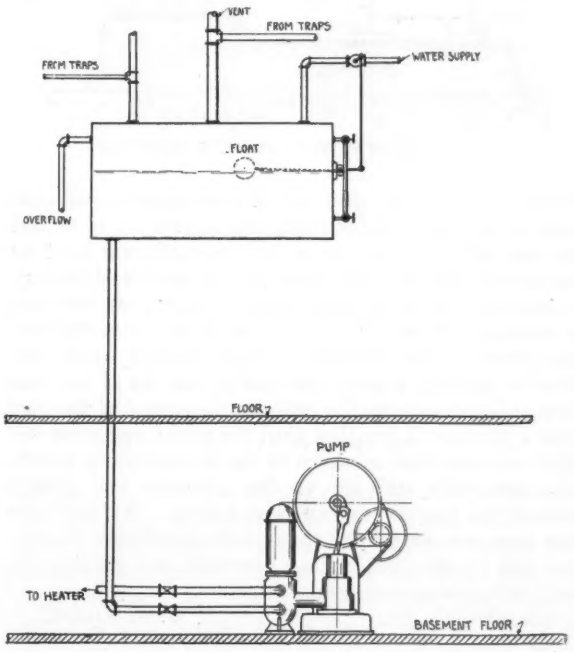
Sometimes I have found a nozzle hole to be too large for the proper feeding of the oil used. The same thing happens as when the nozzle is clogged with sediment. Large drops touch and one ultimately breaks; the glass becomes oil fouled and it is then impossible to tell how fast or slow the lubricator is feeding.

To overcome this defect reduce the size of the hole by taking a piece of smooth iron and gradually working the top edge of the nozzle over by rubbing the iron around and over the top, pressing down lightly or harder as the case requires, and then polishing to a smooth surface. Some men are bothered with sight-feed glasses breaking. If the metal of the lubricator is not touching the glass, top, bottom or sides, and the glasses persist in cracking, be sure the fault is due to the cut ends, that is, if a good grade of glass is used. Use fused end glasses and there will be no further breaks, also use proper gaskets around the glasses. It is a mistake to believe that anything is good enough for a lubricator glass gasket. Often a piece of soft material is used and when the nut is tightened the glass is forced over against the metal. Occasionally clean out the reservoir, tubes and other passages. When shutting down the engine leave the water feed to the lubricator open and close the regulating valve. Then when the oil and water are exposed to a high heat from nearby steam pipes, the expansion volume has an outlet. When both valves are closed it is possible for the body of the lubricator to become distorted by such expansion, if all valves and joints are tight.

Toronto, Ont. JAMES E. NOBLE.

Change in Heating System

M. M. BROWN'S letter in the Feb. 1 issue on page 202, in regard to a change in his heating system, was especially interesting to me, since I am connected with a plant where



PRESENT ARRANGEMENT OF FEED WATER STORAGE TANK

we have the same trouble caused by too small a return and feed supply tank. Our arrangement is somewhat different from Mr. Brown's, since we have a closed instead of an open heater. The accompanying sketch shows the arrangement.

This tank, having a capacity of about 55 gal., is located about 18 ft. above the feed pumps and is supplied from a 1-in. city water line controlled by a float regulated valve. The float is set to keep the tank about two-thirds full. With the vacuum pump discharging from the heating system, there are times when considerable water goes to the sewer. On the other hand, when the heating system is not working there are times when the pump will not get enough water even with the make-up valve wide open.

To remedy this condition, we propose to install a tank of at least 500 gal. capacity and place it at a much lower level with the float valve so arranged that there will be but

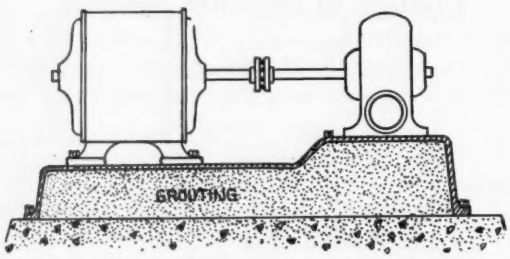
little water in the tank when it opens. With this arrangement there will be a great deal more storage capacity available to take care of an extra heavy discharge from the heating system. G. H. KIMBALL.

East Dedham, Mass.

Trouble with a Flimsy Pump Base

IN OUR plant we had in service for some time a motor-driven service pump which gave us all sorts of trouble, not only in keeping the flexible coupling between the motor and pump in operative condition but in preventing excessive wear of the shaft where it projected through the stuffing-boxes on the pump.

We tried several types of couplings and all sorts of pump packing but we did not lay our hand on the real



BASE PLATE IS STIFFENED WITH GROUTING

source of the trouble until an old experienced pump man made an inspection of the outfit and pointed out to us that the base plate or frame on which the outfit was built up was entirely too light and flimsy for the weight of the outfit, probably due to skimping when the base plate was cast, or oversight in not providing it with ribs to stiffen and strengthen it. He suggested a simple remedy which consisted of tapping a good size hole in the top of the base plate and pouring into the entire inside cavity of the base plate a mixture of grouting until the entire base plate was filled out, somewhat as shown in the accompanying sketch. This noticeably stiffened up the structure and greatly reduced the trouble we had been having. We are quite sure that once we get the opportunity completely to overhaul and fit the pump with a new shaft and packing the outfit will give us complete satisfaction.

Philadelphia, Pa. M. A. SALLER.

Hydrostatic Tests

MAKING HYDROSTATIC tests on materials requiring such inspection in this weather is a serious one with which various plants have to contend.

Some time ago, while making such tests at a valve plant I was informed that it was impossible to hold help long on this work, largely for the reason that the use of the cold water used is chilling to the operator, breeds discontent and is conducive to rheumatism.

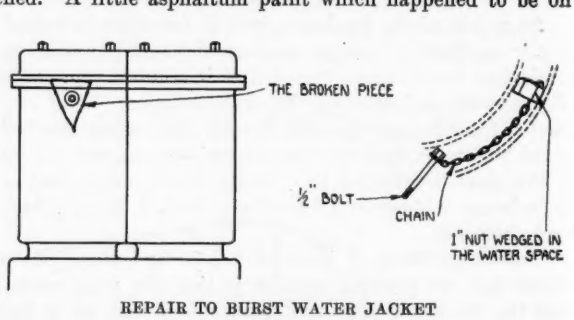
After leaving this particular plant, it occurred to me that hot water might solve the problem. Recently I was delighted to discover my theory put into actual practice by a concern making tanks. While making hydrostatic tests at this plant, I discovered that they were using hot water to the utmost satisfaction of the firm and the help. When I commented on the matter I was informed that this has been their practice for the past 60 yr., that the men never complained of being chilled and nobody had ever had rheumatism.

May we not ask those firms who make hydrostatic tests part of their inspection to give this serious consideration and make a worth while try with hot water. Since the water is used repeatedly, little heating is required after the first heat has been applied.

It is not pleasant, no matter how comfortable the building may be, to be compelled to handle and splash cold water and to handle metals thus chilled in weather like this. S. ROSENBERG.

Repair to Frozen Water Jacket

ONE NIGHT a cold snap came when the air compressor of a portable road-working outfit had not been drained and the water jacket burst, the broken piece falling off. As but few tools were at the camp, a short piece of small chain was obtained, one end made fast in the water space by wedging in a 1-in. square nut and, at the other end a ½-in. bolt was passed through the last link. A hole was drilled in the center of the broken piece, the bolt passed through and tightened. A little asphaltum paint which happened to be on



REPAIR TO BURST WATER JACKET

hand was smeared on the broken edges and the job is doing satisfactory work, all the odds being in favor of its lasting to the end of the contract or until it goes back to the city and be welded. CHAS. LABBE.

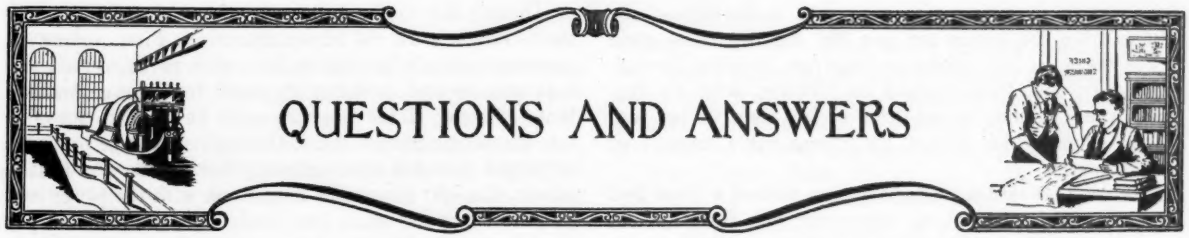
Johnnie, Nev.

Conical Stuffing-box Packing

IT HAS occurred to me in reading over the letter from W. L. S. on page 1152 of the Nov. 15 issue of Power Plant Engineering, that he must have had some trouble in holding the first or outer ring of packing while the second was being placed at the bottom of the box. It would be worth while knowing the reason for making such a conical box; no logical reason suggests itself to me.

It seems to me that a four-piece wedge style packing could be used to advantage in this case. The 1-in. size could easily be forced through the $\frac{15}{16}$-in. opening at the top of the slot and the packing would open and hold tight on both rod and box at the bottom with but little compression on the packing, just enough to force the wedges to fill the box. I have used such packing in boxes having as much space as was in the conical box and had no difficulty in securing tight work. TROUBLE SHOOTER.

THE GREAT power districts of North America rank about as follows: Niagara, taking both Canadian and American sides of Niagara falls, with an output of upwards of 4,500,000,000 kw.-hr.; Greater New York, with an output of 3,596,500,000 kw.-hr. in 1922; Greater Chicago, with nearly 2,750,000,000 kw.-hr.; southeastern California, with 2,363,000,000 kw.-hr. output, and central California, with 2,250,000,000 kw.-hr. output.



Economy of Exhaust Heater

IN ANSWER to the question on the economy of an exhaust heater, by W. T. on page 307 of the March 1 issue, I think almost any engineer's counter-question would be, "Why does not W. T. overhaul the heater and stop the leaks?" If such a simple remedy is impossible, I would suggest that an indicator card be taken on the low pressure engine, at a 26- and 23-in. vacuum.

By computing the difference in the indicated horsepower and transforming that to a B.t.u. basis in accord with the plant performance, the result is easily computed.

Find the indicated horsepower that the 23-in. vacuum gives, and subtract that from the i.hp. with a 26-in. vacuum. The difference is the saving when the heater is not in use. Then compute the number of B.t.u. that the plant consumes under normal operation to make 1 i.hp. Then calculate the number of B.t.u. saved in the heater, by the usual method.

A comparison of the two figures will serve to show whether or not there is saving with the heater.

Brooklyn, N. Y. JOHN U. MORRIS.

Examination Questions on Manning Boilers

SO MANY questions relating to the Manning type of boiler have been asked engineers examining boards and so many engineers have failed in their examination on these questions that I submit a list with the correct answers for the benefit of those who contemplate going up for a license.

1. How can you tell if there are broken stay bolts in your boiler?

A. The only accurate way to determine this is by drilling a hole in the bolt at each end projecting beyond the sheet not less than ½ in. After all are drilled, test the boiler by the hydrostatic test; water will show up at the broken bolts. There are some that test with a hammer but it is not a reliable method. A friend of mine just had 15 bolts condemned and in taking them out only 2 were found to be broken. If I were in charge of Manning boilers every stay bolt would be drilled or I would refuse to run them.

2. How do you find the safe working pressure?

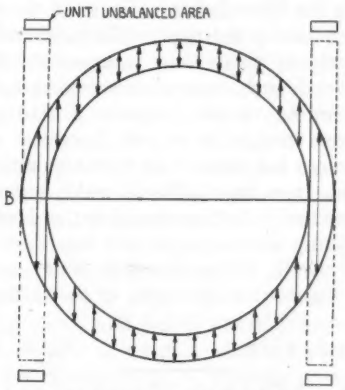
A. The barrel of the boiler, the stay bolts that support the inner sheet, the space between the stay bolts and the ogee ring must be taken into account. The regular formula is S.W.P. $= t \times$ T.S. $\times$ E $\div$ (R $\times$ F.S.). The strength of the section of the lower course between the stay bolts and the ogee ring is found in the same manner as the shell proper. In most modern boilers there is a reinforcing ring used which is riveted to the shell. This strap strengthens the sheet so much that it is not necessary to consider this part of the boiler. The rivets would have to shear before the shell could let go. For stay bolts use the regular formula for flat surfaces.

3. Why do you not have to figure the outer sheet of the water leg?

A. The stress on the outer sheet is small only the depth of water leg times the pressure.

4. How do you find the stress on the outer sheet and why do you use the depth of water leg in place of the diameter of the boiler?

A. The stress is the depth of water leg times the pressure. And the reason that I use the depth of water leg is shown on the accompanying sketch. The space between the projected area circles is balanced because of the use of stay bolts, put in to prevent the inner sheet from



UNBALANCED AREA OF A MANNING BOILER

collapsing. They also support the outer sheet, which gives a balanced leg inasmuch as the effective area would be the same in the balanced space if you had two flat surfaces. At any point, as for instance B on the sketch there is a force tending to tear the outer shell. This force on a unit length of shell is equal to the radial distance between the inner and outer shell times the length of the unit section times the pressure. The greater the space between the two sheets, the greater is the bursting pressure, as you have a greater projected area that the sheet must support. If you had no stay bolts the outer sheet would have to be figured as any cylindrical shell for you would have the same effective area tending to tear the shell apart and there would be no stay bolts to balance any part.

4. What is the Sundgberg ring?

A. This is a reinforcing ring of boiler plate riveted on to the shell where pipe connections have to be made.

L. N. W.

Applicability of Traps

REFERRING TO W. J. M's. question in the Feb. 1 issue regarding traps on condensate lines, let me say that I am also in the paper mill business and would suggest that he leave his present system of handling condensate through the 800-ft. line from the paper mill to the boiler house

alone. If he is drying with exhaust it is doubtful if the returns from the dryers are over 220 deg. F. unless some of the traps on high pressure drips are blowing through badly. To cool these returns to 190 deg. with 60 deg. water would require the addition of less than 25 per cent of the drips, which is not an unreasonable amount of makeup water.

I know that return traps have been pushed a great deal for work of this sort but our experience with them has not been particularly satisfactory as they sometimes require more attention than a pump. The high temperature water they return to the boiler has been heated with the most expensive heat around the mill, high pressure steam. Another disadvantage of the return trap is that when it lies down it is hard to tell what the trouble is as its functions are so interconnected. With a duplex pump it is usually easy to get it going again. For delivery to boilers return traps can not be set too high above the water line of the boiler, 15 ft. is none too much as this head must overcome not only water friction in pipes, check valves, etc., but also the drop in steam pressure between the boilers and the trap.

If the return lines in the office cannot be rearranged so as to grade the hotwell, I would suggest the installation of a small receiver in the paper mill basement with float controlled pump to pump these returns into the hotwell. We have several such arrangements working perfectly. From the wording of the question a return trap has apparently been tried on it without success.

Without more information as to the quantity of water to be handled, it is impossible to make any estimate of the power required in either case but the discharge pressure at the pump in the paper mill basement should not exceed about 15 lb. unless the feed water heater is set considerably higher than indicated in the sketch. For the office line it should be not over 5 lb.

New Haven, Conn. H. D. Fisher.

Central Station Service vs. the Isolated Plant

Referring to the question by O. P. I. in the Feb. 1 issue concerning the advisability of subsituting central station service for the isolated plant, it is well to bear in mind that there are always many things to think of when considering the matter of purchasing power. To offer an intelligent answer to this question, more data regarding conditions in the plant should be available.

From the figures given, it is apparent that the load on the engine is between 125 and 150 hp. It is assumed that none of the exhaust steam from the engine is used in the manufacturing processes and there is plenty for heating purposes during the winter season. Ordinarily there would be about 1500 hr. a year when a man must be employed to attend the boilers to furnish steam necessary for heating. If it is necessary to heat the plant during the night or over Sundays and holidays, someone must be employed for this work also but it is possible that the night watchman would serve when he is on duty.

If electric power were purchased during the non-heating season, the saving in labor might offset the requirements during the heating season. If the present engine is not in first class condition and able to operate with a comparatively low water rate, it would seem that it would be more economical to use central station energy, at least during the summer months.

During the winter either one of two possible arrangements might work out advantageously: First, reduce the pressure on the boilers to 15 lb. so that an unlicensed fireman may be used, and buy all power from the central station. Second, if the pressure must be kept up for some manufacturing process and if the engineer can be profitably employed in some other capacity during the non-heating season, it might be possible to contract with the power company to carry the whole load during the summer and part load during the winter. This, perhaps, would be the more satisfactory arrangement.

East Dedham, Mass. G. H. Kimball.

Forced Draft Fan or Higher Stack

In reply to the question asked by F. S. in the Feb. 1 issue on page 203 concerning the advisability of using forced draft and reducing the height of his stack to 30 ft., I would say that my own experience with under-grate blowers has indicated that they will give all the draft necessary and that the main consideration is having enough stack draft to remove the products of combustion. If the uptake draft is not sufficient, a positive pressure will be built up over the fire and the furnace gases will be forced out through every crack in the setting into the boiler room. It would seem that reducing the height of the stack would make the natural draft extremely sluggish so that the operation of an undergrate blower would make conditions in the boiler room exceedingly disagreeable.

Recently I had charge of the installation of the 300-hp. water-tube boilers which were served by a stack 100-ft. high by 3 ft. 8 in. square. Each boiler was equipped with an undergrate blower. When the units were put in operation, it was found that the stack would not remove the gases fast enough for more than 125 per cent of rating. This has been sufficient up to the present time but if more load is to be carried, an induced draft fan will have to be installed.

I would recommend that F. S. install an induced draft fan in his plant.

East Dedham, Mass. G. H. Kimball.

In answer to F. S's. question in the Feb. 1 issue, regarding the use of an undergrate blower in preference to rebuilding his chimney to a height of 70 ft., I would suggest that he rebuild the stack for the following reasons:

A 30-ft. stack would give barely enough draft to overcome the friction of the gases through the boiler at rating and if any higher capacity were needed, the blower would develop a pressure in the furnace resulting in rapid deterioration of the furnace brickwork.

Except where economizers or other apparatus might be profitably installed to use the heat of the flue gases, the chimney has no operating expense and maintenance, including painting, will probably not exceed that on a fan.

Owing to the increased resistance due to friction in the boiler and chimney caused by the greater flow of gas when fires burn thin, the firebox draft is reduced and the flow is checked to a certain extent. This action tends to make the system of chimney draft more self regulating and has less tendency to burn holes in the fire. With a fan there is no such restraining resistance and as soon as one spot thins down a little the air flow through it increases, resulting in rapid burning out of holes. In this way the excess air will be increased, resulting in lower economy and the boiler will be subjected to greater variations of furnace temperature between the good fire when everything is right

and the large rush of cold air when holes are burnt through.

This tendency is so well recognized that no attempt is made to burn small sizes of anthracite except on pinhole grates in which the air space is so small that should the fire show thin spots, the friction of the increased flow through the small grate openings will keep the whole flow from concentrating there and killing the pressure on the rest of the fire.

New Haven, Conn. H. D. FISHER.

Refrigeration Plant Operation

IN ANSWER to J. B.'s question on page 203 of the Feb. 1 issue of Power Plant Engineering concerning the charging of an ammonia system, I would say that I have always had good luck in charging the system by simply closing the king or expansion valve and after connecting the drum to the system charging line, I simply open the drum valve about halfway until the charging operation gets well under way and I see there will be no leaks, then I open it as wide as I think is safe to have it. I do not touch the expansion valves, for when I have them set I hate to disturb them.

One good way to tell when the system needs a new charge is to note when the liquid in the receiver glass stops boiling and appears to be dead. Do not be guided by the fact that there is no liquor in sight in the glass, as I have had the pipe between the condenser and the receiver get plugged and the gas all worked out of the receiver but the condenser was nearly full when I got wise to the trouble.

To pump out your ammonia receiver, close the valve between the condenser and the receiver and let the condenser be your receiver. Then pump out your receiver through your king valves and when you have a small amount of vacuum in the receiver, shut the main king valve on your receiver and proceed with your repairs.

Rochester, N. Y. R. G. SUMMERS.

Secondary Air

REFERRING TO H. C. R.'s question in the Feb. 1 issue on the advantage of making passages in the bridge wall for admitting secondary air from the ashpit to the firebox for improving combustion, I do not believe he will find it any advantage and will probably find it a detriment unless the passages are arranged so that only a small amount of air is admitted and this is heated to at least 400 or 500 deg. F. Several years ago I assisted at a series of rather elaborate tests of a smoke consuming system for locomotives where various quantities of secondary air were admitted at various temperatures, accurate measurements of everything including density of smoke being made and it was found that at the lower air temperatures while the density of the smoke was decreased somewhat the capacity of the boiler was decreased also in just about the same proportion as the secondary air was increased and it was not until the higher temperatures of 400 to 500 deg. F. were reached that capacity could be maintained and smoke reduced.

Unless, owing to local conditions, smoke is highly objectionable, the actual loss in heating value of the carbon passing up the chimney in the smoke is probably not serious, seldom over 1 or 2 per cent, a loss which might easily be several times overbalanced by misuse or careless regulation of secondary air. A more serious possibility of loss is that with too heavy firing larger quantities of hydrocarbon gases are distilled than can be consumed with any reasonable quantity of secondary air and these pass up the chimney unburned. The remedy for this is more frequent and lighter firing, either by the coking or alternate system, which will of itself greatly reduce smoke and equalize the demand for secondary air, enough of which is usually admitted in the ordinary type of furnace door.

New Haven, Conn. H. D. FISHER.

Measurement of Oil Viscosity

WILL YOU kindly give me information as to how I may construct an apparatus for testing the viscosity of oil? Occasionally we get a shipment of lubricating oil that is seemingly inferior to the normal run and I want to be able to test it for viscosity. R. S.

A. Viscosity is a measure of the internal friction of a fluid friction may be used to determine viscosity. There fluid, hence any method that can be employed to measure are several different kinds of apparatus available for making this test; among them might be mentioned the Saybolt meter, the Engler, Michell, Ostwald and Redwood.

For the purpose of comparing the viscosity of any two oils any simple method of measuring the time required to discharge a given amount from any container through any size orifice under identical initial head conditions and at a constant temperature will suffice. The longer the time required, the greater will be the viscosity.

If it is desired to make a more elaborate instrument one may be fashioned after the design of one of the commercial meters. The Saybolt meter, for instance, is essentially composed of a covered oil receptacle of a carefully determined shape and size, provided at the bottom with a standard orifice and a valve, the valve being constructed quickly to open or shut the orifice as desired. The cup is supported in an outer cup, which is filled with a pale engine oil of about 375 deg. F. flash-point, or, for some cases, water is used as a bath in the outer cup.

Briefly, the measurement of viscosity with the Saybolt instrument may be described as follows: The oil cup is filled with a standard quantity of the oil to be tested, and after it has been heated to the desired temperature and kept constant for two or three minutes the bottom orifice is opened. The oil is then run into a 60 c.c. flask and the number of seconds, as noted by means of a stop-watch, that are required for the flow of the oil through the orifice into the flask to fill it to the 60 c.c. mark is reported as the viscosity of the oil.

The standard dimensions of the Saybolt Viscosimeter are as follows:

	Inches
Diameter of outlet tube	0.0695
Length of outlet tube	0.482
Outer diameter of outlet tube at lower end	0.118
Height of overflow rim above bottom of outlet tube	4.92
Diameter of container	1.17
Temperature for testing cylinder oil	210 deg. F.
Bath	212 deg. F.

TO CLEAN belts, if the belting is not brittle or rotten, a thorough wiping off of the excess of oil and scraping the face with a sharp tool to take off the gummy matter and finally wiping the inside with a little naphtha or gasoline upon a cloth, will generally restore the belt. The pulley should be cleaned also. If the belting has become weak and rotten, it should be thrown away.

POWER PLANT ENGINEERING

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Limits for Profit Making

Our industries are confronted with the problem of taking their profits from the confines of two price levels. The one price level is that of the raw materials and labor which must be used in the process of production and the other is that which the finished products will bring upon the market.

Every industry is made up of a number of individually operated companies each of which is strictly accountable for its own destiny. These companies find when they go upon the market for raw materials, that prices are quoted at which their competitors can buy the same material. They also find, when they offer their finished products for sale, that the market will allow a certain price and no more. Their competitors also get this same price for products of equal quality. This means that the profit, which can be made by any individual company within a given industry, must come from between the general price levels of raw material and labor and the sale price of the finished products. It is not within the power of the company to stay in the field and depend for its profits upon the buying of cheap materials or upon a sale price higher than is consistent with the quality of its products.

Whether a company will prosper or fail will depend in a great measure upon how raw materials and labor are used. Some companies will operate economically and strengthen their position in their field while others will blunder along until they are finally forced to drop out of the race; in fact, they will probably be absorbed by those companies which have been operated with good judgment and foresight.

It would appear that the manager of an industrial concern would not knowingly waste 40 to 50 per cent of his raw material, yet this is being done day in and day out with coal which is a raw material. An alert manager would not countenance a loss of 20 to 30 per cent of his finished product between the time that it leaves the machines and the time that it is loaded upon cars for shipment. Nevertheless, this is exactly what is being done in the distribution of power in the average industrial plant. Further, an active manager would not long tolerate the use of hand labor to wrap his product when one man could operate five or six automatic machines each of which had many times his capacity by hand labor. Hand labor methods are in use when obsolete power plant equipment is operated and when inefficient methods of power distribution and application are allowed to exist.

Productive economy cannot be realized in full unless the use of raw material and labor in the power plant is put on an equally efficient basis with the remainder of the plant. The manager who does not bring his power plant up to a consistent standard of productiveness is neglecting to take the full legitimate profit which is available to him. He is giving his more wideawake competitors an advantage which will become more and more difficult to overcome as time goes on.

Something Wrong

While in a power plant the other day the writer made the acquaintance of a steam fitter. Almost immediately he began putting questions to me regarding some of the details of his work. One question was what is meant by a 4-ft. radius bend, others were as fundamental to his work.

This man was a full fledged tradesman having spent a full term as an apprentice and several years as a steam fitter yet lacked elementary knowledge vital to his work and absolutely essential to a man assuming responsibility for a job of pipe fitting.

Further conversation revealed that the reason he had not learned some of these terms from his foreman was that he had not asked him. In fact, he seemed afraid to ask because he thought the foreman would put him down as incompetent, when, as a matter of fact, he had worked under this same man for several months and was able to perform his mechanical jobs with satisfaction.

Were this an isolated case, we could set it aside but the fact is few industrial organizations exist where some men do not take a similar attitude toward their work. Here was a man who honestly wished and was perfectly able to learn more about his trade; he had at his elbow an excellent opportunity to obtain this knowledge yet through pride or fear he has allowed himself to work for years in plain downright ignorance.

Something is decidedly wrong with a system of employment which will cause men to take such an attitude toward their work. Every man in a subordinate position is entitled to a certain amount of instruction or teaching from his superior. No man in an executive position wants the work under his direction to stop the minute his back is turned, yet he cannot expect much else, if his men are not taught the whys and wherefores of the work they are doing. Too frequently, men hold their positions by bluff, which on the part of the executive is sure to be reflected by lack of confidence on the part of his assistants. Again, executives frequently make the mistake of secreting from their subordinates, information needed in order to do the best work, causing mistakes which are not in the least due to the subordinates' ignorance or inability.

In the power plant, greatest success will be attained by the men who gain the confidence of their assistants, who are able to instruct without offense and hold their men's interest in their work by a process of continuously developing them for more intricate and important work. A little display of the milk of human kindness will right many a wrong.

What Is Reliability Worth?

On entering upon a production enterprise of whatever nature, be its product electric power or automobiles or any one of the 57 or so varieties, a company's chief object, frequently its sole object, is to show a profit over a period of years. Inasmuch as this profit represents the difference between the gross income and the total production costs, it is evident that, if the gross unit income is fixed by trade conditions, the unit production cost must be reduced to a minimum in order to realize a maximum of profit. Whether this minimum production cost is to be secured by maximum efficiency of operation, by maximum reliability, by minimum first cost of equipment or by any combination of these items in any proportion, is a question not to be decided in an arbitrary manner. It is a problem that must be given careful consideration from both the engineer's and business man's point of view, weighing all factors that have any bearing on the situation.

Take the case of a power plant for example, either a central station producing electrical energy to be sold or an isolated plant supplying energy for manufacturing purposes; in its design, provision must be made for certain vital auxiliary drives. At this point there is a wide variety from which to select. In the first place, either primary or secondary power may be used. The first group includes the steam engine and the steam turbine; the second, all the various types of electric motors. Among these various systems, efficiency, reliability and first cost as well as adaptability and convenience vary within wide limits.

To make a comparison of the relative importance of these factors, it is convenient to reduce them all to a common monetary denominator. In the case of the two items, efficiency and cost, this is a comparatively simple process but to place a dollars and cents value on reliability is quite another matter. The influence of first cost is found simply by assigning a fixed charge to cover interest on the investment, depreciation, insurance, obsolescence and maintenance. The money value of efficiency may be found by figuring back the steam or kilowatt-hour consumption to the cost of steam or electric energy. It should be remembered, however, that the individual efficiency of one particular piece of apparatus does not constitute the whole story; the effect of the apparatus in obtaining a desirable heat balance and on the efficiency of the plant as a whole must be taken into consideration.

To determine the money value of reliability requires an accurate analysis of all the circumstances under which the equipment is to operate. It varies widely, depending largely upon the nature of the product and the consumer and is exceedingly difficult to ascertain, even approximately, because it involves intangible factors as, for instance, the good will of the customer. With a thorough knowledge of the business, a valuation may be placed on good will and the extent to which any interruption of service is liable to damage it. This or the readiness-to-serve charge of an emergency tie-in line added to the actual loss of revenue occasioned by a forced shut-down and the cost of effecting a repair may be fairly listed as the value of reliability to be borne in whole, not pro rated, by every vital piece of equipment.

Comments From Readers

That every reader of these columns should be able, without reservation of any kind, to subscribe to every idea presented to our readers for their enlightenment is unthinkable. To be sure, much of the material published is statement of fact and as such is indisputable but wherever opinions are advanced, there is always room for another point of view. An opinion is the result of the exercise of logic on a given set of facts or conditions and whether or not you agree with an author will depend on whether your logic is the same as his. Any man's reasoning processes are largely a result of his past experience and inasmuch as experiences vary it follows that reasoning processes must vary, hence conclusions drawn from certain hypotheses must necessarily differ somewhat.

The point is that anyone who does his own thinking must, on occasion, hold views that differ from those of the authors of articles published in these pages and that he would be doing himself and his brother readers an injustice by not expressing them. If you hold a different opinion let's hear it. Our department "Letters Direct from the Plant" is maintained for just that purpose. It is there for your use; use it. It is there to give expression to readers' opinions.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

P. G. S. Burner Adapted to Burn Low Grade Oil

AN INTERESTING application of the syphon principle is made in a new oil burner, recently placed on the market by the Combustion Engineering Corporation, of New York. This device, known as the Quinn P. G. S. burner, has been designed especially to meet the requirements of refinery work but can also be installed with equally good results under steam boilers of any size.

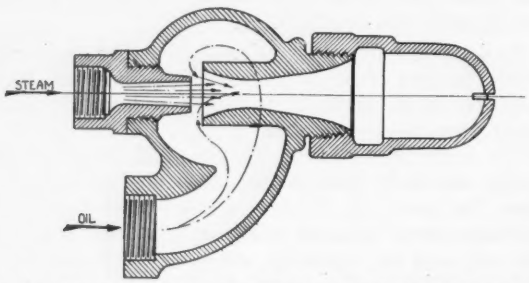


FIG. 1. CROSS SECTION OF THE MIXING CHAMBER OF THE P. G. S. BURNER

P. G. S. stands for pressure, gravity, syphon, and as the name suggests, this burner utilizes the syphon principle. Oil may be fed to it by either pressure or gravity. It is made in various sizes and capacities to meet all refinery requirements, including the firing of large and small steam boilers. One of its best features is its ability to utilize low grades of oil and tar containing considerable sediment. This is largely due to the fact that the oil never has to pass through an opening less than 3/8 in. in diameter, consequently there is no possibility of the burner passage becoming clogged. Another feature of this burner, more important perhaps in refinery practice than in boiler plants, is its ability to maintain a uniform temperature under still furnaces, etc.

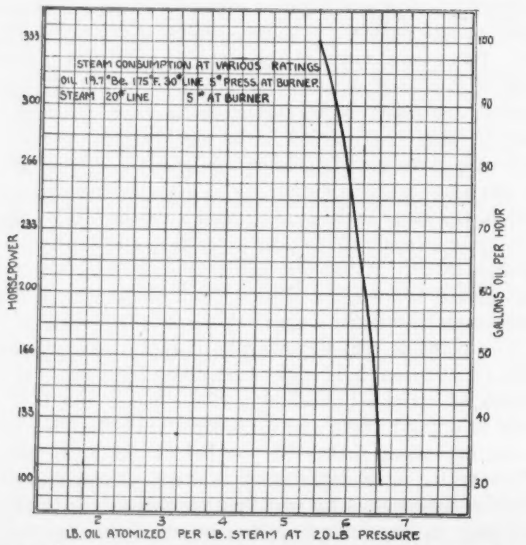

STEAM CONSUMPTION AT VARIOUS RATINGS
OIL 19.1° Be. 175° F. 30" LINE 5" PRESS. AT BURNER
STEAM 20" LINE 5" AT BURNER
HORSEPOWER
GALLONS OIL PER HOUR
LB. OIL ATOMIZED PER LB. STEAM AT 20 LB PRESSURE

FIG. 2. CURVE OF A TEST ON THE P. G. S. BURNER

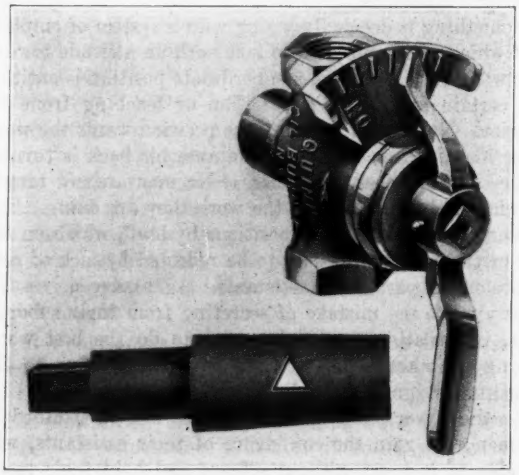


FIG. 3. QUINN OIL REGULATING COCK AND V PLUG WHICH REGULATES THE FLOW IN THIS COCK

When acid sludge or other fuels which are damaging to ordinary metals are to be burned, this burner can be furnished in monel metal.

Ordinarily, however, these burners are made of brass throughout with the exception of the standard wrought iron pipe connections. As will be noted from the illustrations, the steam enters through the upper pipe and the oil through the lower. In the mixing chamber shown in the cross-sectional view, the oil rises to about the base of the cups. As a result of the whirling motion given to the steam, which expands over the curved surfaces in a manner similar to the expansion which occurs in a steam turbine, the oil and steam became intimately mixed and fill the entire chamber.

This mixing chamber serves as a reservoir and tends to prevent the sudden changes in the size of the flame which are apt to result from fluctuations in oil or steam pressure. This action is comparable to the action of an air chamber on a pump in steadying the discharge pressure.

As mentioned previously, oil may be fed by pressure or gravity. As low as 20 lb. per sq. in. steam pressure will effect complete atomization of the oil.

Steam can be admitted to the oil line by means of the globe valve shown between the oil and steam pipes. This

makes it possible to give the oil line a thorough cleaning whenever it is needed.

In action, the makers claim, this burner is extremely economical. Either steam or air may be used for atomization purposes. Where steam is used no more than one per cent of the total steam generated is required for complete atomization. The accompanying chart shows the steam consumption at various ratings. In one instance this type of burner atomized an average of six pounds of oil per pound of steam, operating continuously over a period of five months.

For controlling the oil flow to the burner, the cock shown in Fig. 3 may be used to advantage. The V notch shown in the plug permits a fine regulation of oil flow.

Improvements in the National Hand Stoker

M. A. HOFFT CO., of Indianapolis, Ind., recently made improvements in their National hand stoker which will facilitate the quick and complete cleaning of clinker. The change made affects the rear dumping plates in that the center support for the dumps, which formerly extended across the dump opening from the bridge wall to the bottom bearing bar has been cut off at the trunnion bearings. This change makes a dump opening the entire width of the furnace with no obstructions to the cleaning of the grates. The removal of this bar eliminates the possibility of anything holding up the clinker.

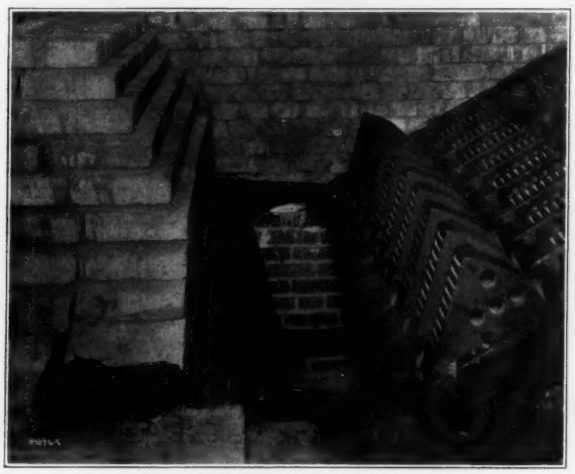


FIG. 1. NATIONAL STOKER WITH DUMP PLATES IN DUMPING POSITION AND BOTTOM ROW OF PUSHERS RAISED

It is also possible to lift the dump plates about 4 in. above the normal closed position before dumping in order to loosen the clinker. The dumps are then dropped and all ashes and clinker is discharged into the ash pit.

In spite of these features, it sometimes happens, especially on heavy firing with bad coal, that the clinker does not drop out so easily. If this occurs, the clinker can be kicked out through the dump opening by pulling the bottom row of pushers shown in Fig. 1. This is done without disturbing the good coal in the top and without loss of good fuel. The pushers and grates at the upper end are not disturbed. The fuel pushers operate between the stationary bars raising about 10 in. which is sufficient to break up and throw out any coke or clinker. It has been found that the 30-deg. angle on the stationary grates will not permit or cause any avalanching of the fuel when the dumps are open.

Figure 1 shows the National hand stoker in the dumping position and with the bottom row of pushers in the raised position. The absence of the center bearing bar is apparent. The travel of the pusher up through the grate

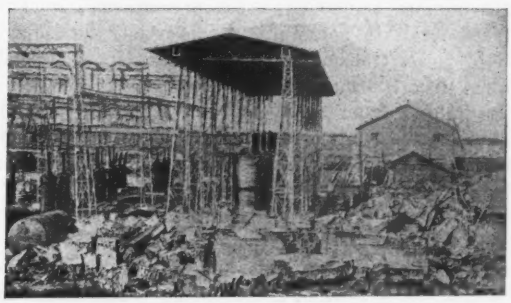
FIG. 2. STOKER WITH DUMP PLATES SLIGHTLY RAISED TO BREAK CLINKER

is approximately 10 in. After the clinker is kicked out, pushers are dropped back in place, the dumps are raised and good fuel at the top is shoved to the lower end of the grate.

Figure 2 is a photograph of the grate with the rear dump in position and the other dump plate raised. This dump can be raised by pulling up on the dump rod in front.

Transformers Withstand Earthquake

DURING the recent earthquake in Japan, the substation of the Gumma Denrioku Kabushiki Kaisha, an electric power company in Tokio, was completely demolished. With the exception of three 3500-kv.a. Westinghouse transformers, all apparatus in this station was destroyed. The switchboard and auxiliary equipment was damaged beyond repair.



VIEW SHOWING TRANSFORMERS AMONG THE RUINS OF TOKIO SUBSTATION

Reference to the accompanying photograph will serve to give some idea of the utter destruction. The foundation under the transformers inclined some twenty degrees under the stress of the quake and was damaged considerably. In spite of this, however, the transformers were found to be in good condition, and are still supplying current for railway, light and various power uses.

Engineering Societies Hear Paper on Superpower

"THE REAL Meaning of Superpower and Its Relation to Railway Electrification," was discussed by W. S. Murray, of Murray & Flood, in a paper presented at a joint meeting of the metropolitan sections of the A. S. C. E., A. S. M. E., and A. I. E. E. at the Engineering Societies Building in New York on Feb. 27.

After referring to a recent statement of Herbert Hoover that "The Superpower Report has been off the press for over three years and nobody has kicked a hole in it yet," Mr. Murray summarized the findings of this report as follows: "If the electric utilities co-ordinately expand to supply industry and the railroads through the means of a regional pool of large steam and hydroelectric power plants generating their energy at strategic coal and water points, the territory between Boston and Washington and inland from the coast 150 mi. can be supplied with an initial expenditure of about a billion and a half dollars and the savings as of 1930 compared to the operations of 1919 will be over $500,000,000 annually."

Condemning as "economic iconoclasts" those who would define superpower as a giant trust for purposes of rate control, the speaker declared that the real meaning of the term is being generally interpreted as "power better than that which has been produced in the past." The improvement is based on more adequate, reliable, and economical generation of power. To bring this about, four facts must be recognized:

(1) "Maximum commercial efficiency in generation, transmission, and utilization of power is secured when, for minimum capital expenditure, maximum power adequacy and reliability, with the highest operating economy, is reached.

(2) "Minimum steam generated electricity is secured when maximum water power generated electricity is associated with it.

(3) "The greater the interconnection between steam-electric and hydroelectric plants, the greater the opportunity of producing hydroelectric energy.

(4) "Power can now be reliably transmitted at potentials as high as 20,000 v., which pressure will doubtless be exceeded. With potentials of this order, the economic radius of power transmission has increased in a few years from less than 100 mi. to over 300 mi.

"It follows from these four points that maximum economy in electric power production will be secured through co-ordinate regional expansion of electrical utilities, and I would add—*under public supervision.*"

While electric utilities have practiced superpower principles in the past so far as possible, new instruments of greater possibility are available, and only the time required to manufacture equipment and construct transmission lines retards the more ample application of these principles and the realization of maximum economy.

While the resources of our country are marvelous, it is true that the more we conserve water the less we conserve coal. Not much water power is available in the eastern zone to which reference has been made. Of the total conservative estimate of 1930 demand for this section, only twenty per cent can be supplied by water power.

Further reference was made to the "economic iconoclasts" in connection with the defeat by referendum in California of their "Water and Power Act." The real slogan for the American public is not "Power at cost" but "Power at *what* cost?" "I do not want to pay for power 'at cost,' said the speaker: I want to know what it costs to produce, and I also want to know the profit made while it is being produced." The power business should be profitable, and investment in it open to all. Accounting of Public Service Commissions should show (1) how much money was expended to make the power, and (2) how much money in dividends was returned to the security owners. Under municipal or public ownership, low power bills are made up in taxes.

The remainder of the paper dealt with railroad electrification in relation to superpower. Two considerations were shown to have retarded progress: (1) Lack of credit, and (2) The old dispute as to the kind of electrification system. A plea was made for sane business methods in developing both power and transportation, with public regulation.

Webster Return Tubular Boiler

SOME interesting claims are made for the "Webster" improved return-tubular boiler, the tube sheet of which is shown in the accompanying illustration, in comparison with that of an ordinary return-tubular unit. One

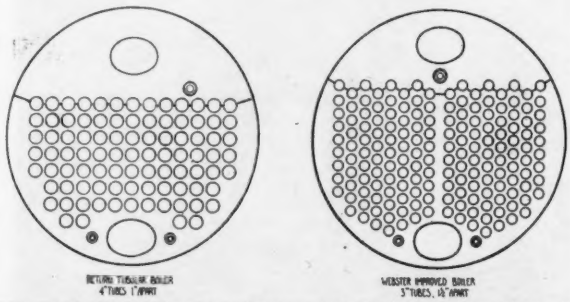


DIAGRAM SHOWING ARRANGEMENT OF WEBSTER BOILER TUBE SHEET TOGETHER WITH THAT OF COMMON H. R. T. BOILER

claim is that the Webster boiler has a much larger disengaging area for a given size and therefore a higher rating.

In both diagrams, a heavy line drawn across the top row of tubes represents the disengaging area, which is the space between the tubes through which the steam and water must pass as the steam is rising to the surface from being generated.

On the type shown at the left, the disengaging area is 22.27 sq. ft. On the Webster boiler it is 43.69 sq. ft. Reference to the marks and Davis Steam Tables shows that for an ordinary return-tubular boiler rated at 192 hp. at 100 lb. pressure the upward velocity of steam and water is 32.47 ft. per min. About 30 ft. per min. upward velocity is the safe velocity above which velocity the water carries over with the steam. In the Webster design, for a 260-hp.

boiler at 100 lb. pressure it is claimed that the upward velocity is only 23.11 ft. per min. under which the steam is dry.

These are the reasons for the use of the hexagonal or beehive tube layout. It results in a maximum number of tubes in the available space or segment of a circle.

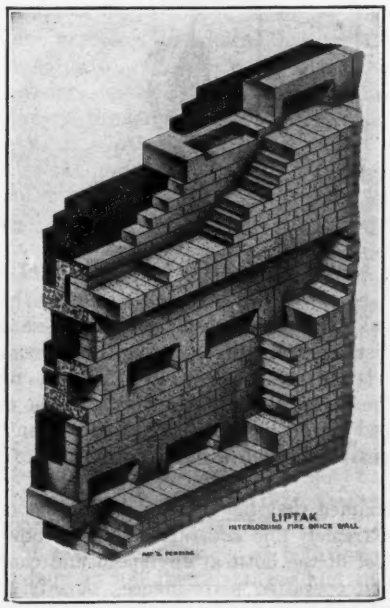
These boilers are built according to the A. S. M. E. Code with the first head inverted. This construction permits riveting each of the girth seams with a bull riveter.

Each boiler is equipped with the fixed-nozzle type of tube blower, each tube having a separate nozzle. The entire bank of tubes is divided into five sections, so that there is no flare-back of fire at the time of blowing the tubes.

The boiler is made by Howard J. Webster, of Philadelphia, Pa.

Liptak Interlocking Fire Brick Wall

WITHIN THE PAST few years marked progress has been made in the development of boilers, stokers and furnaces and the methods employed in burning different classes of fuel have changed materially. These progressive steps in power plant design and practice usually met with higher furnace temperatures which resulted in a shorter life of the boiler brickwork. Various means were therefore developed to prolong the life of boiler furnaces.



VIEW SHOWING DETAILS OF LIPTAK INTERLOCKING CONSTRUCTION

In this direction, the Liptak Interlocking Fire Brick Wall proved successful due to the fact that with this type of construction certain sections of the boiler wall can be repaired without danger of the unimpaired section falling into the furnace. This furnace wall construction is illustrated in the accompanying cut.

As noted, the headers or shelf brick are keyed into refractory retaining blocks, which are imbedded in the outside wall. The method used in keying these header or shelf brick is nothing more than a key wedge brick. The headers extending out from these retaining blocks form a shelf much the same as a shelf in a bookcase and upon which rests several courses of fire brick up to the next row of fire brick headers forming a shelf above.

With ordinary header and stretcher construction, there is no permanent bond or tie between the inner fire brick lining and the outside walls; for this reason, there is nothing to prevent the inner lining from pulling away from the outside lining. With the Interlocking Fire Brick Wall, a permanent tie is maintained between the furnace lining and the outside wall approximately every 22 in. in height.

It is a well recognized fact that a fire brick under compression is much more susceptible to erosion and a clinker action. With the Liptak Interlocking Fire Brick Wall the weight of the inner fire brick lining is transferred through the shelf brick back into that part of the wall which is comparatively cool. By distributing the weight to the cool portion of the wall, this naturally relieves considerable compression from the inside furnace lining. The largest portion of the Interlocking Wall is built into the outside wall where the furnace gases will never reach these brick and this portion of the construction is permanent. Only one brick—the header or shelf brick—is required for repairs. The actual repairing is simple and the shelf brick are removed by inserting a rod through the outside retaining blocks and dislodging the wedge brick.

This type of construction is flexible in design and can be adapted to practically any thickness of wall, to special air cooled walls, and in the design of bridge walls and center walls. It is manufactured by the Liptak Fire-Brick Arch Co., of Chicago, Ill.

Falk-Bibby Flexible Coupling

AS A PRINCIPLE, flexibility in machine couplings has long been considered a desirable accomplishment. It is claimed for the Falk-Bibby Flexible Coupling shown in the accompanying illustrations that they put into practice that which has been accepted as the proper theory for

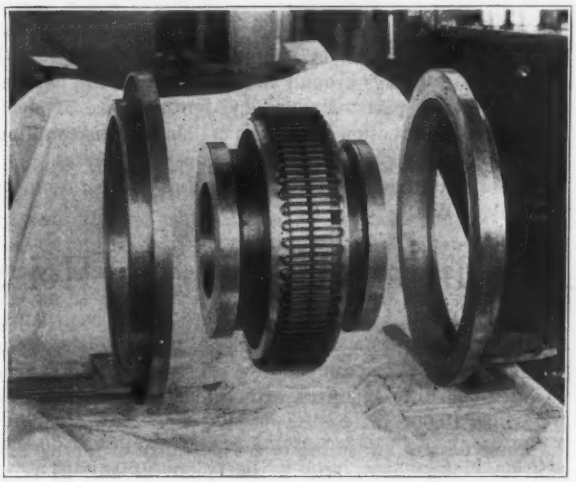


FIG. 1. FALK-BIBBY COUPLING FOR LARGE EQUIPMENT

cushioning heavy shocks and damping out torsional oscillations.

This coupling, used for the transmission of power between shafts of slight parallel or angular misalinement, attempts no actual replacement of rigid parts within clear-

ances provided for that purpose, nor does it utilize rubber or any other soft material for accomplishing its results.

It consists, rather, of especially constructed grid springs of tempered steel, through which power is transmitted between two flanges. The elastic property of these springs affords true flexibility and provides for the smooth transmission of power from one machine to the connected machine. The special feature of this coupling is the action of the springs in engaging with grooves around the periphery of the flanges. These grooves, which flare inwardly toward each other, fit the springs at the ends farthest apart, giving the coupling extraordinary shock absorbing ability and torsional resiliency.

The flexibility of the springs, the manufacturers claim, is always properly proportioned to the load. Under a light load each element is flexed between points separated by the maximum distance. As the load increases, the springs

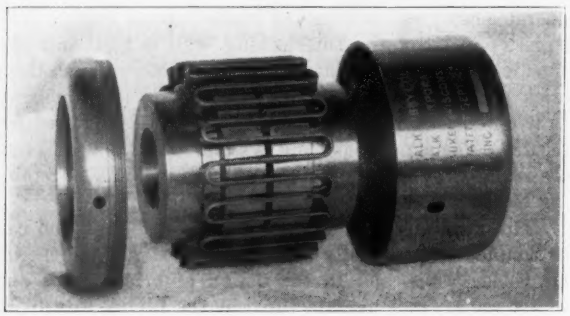


FIG. 2. SMALL TYPE OF FALK-BIBBY COUPLING

wrap themselves around the walls of the grooves, with their inwardly flaring construction and the proper curving of these grooves makes it possible for the increasing load to shorten the effective span of each spring element thus causing it to offer greater resistance to flection without increase of stress.

All working parts are enclosed in a floating shell which provides space for the packing of lubricant. The shafts are alined as easily as with flange couplings, and disconnection is accomplished by simply releasing the shell and removing the springs around the periphery of the flanges.

All working parts—flanges and springs—are of steel. Distinctive construction makes it possible for this coupling to be kept within convenient dimensions in all cases.

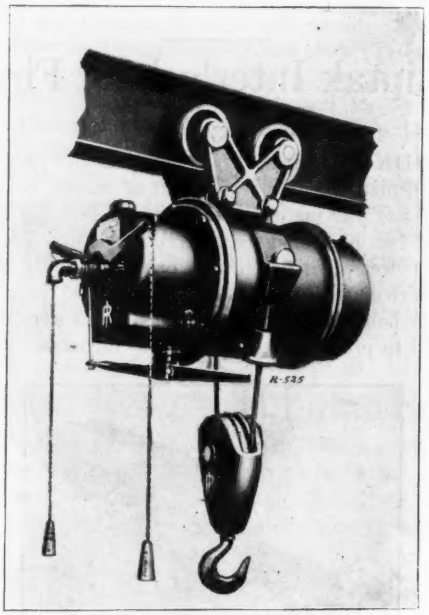
These couplings are made by the Falk Corporation, of Milwaukee, Wis.

New Ingersoll-Rand Air Hoist

INGERSOLL-RAND CO., of New York has placed upon the market a new line of air motor hoists of the type shown in the accompanying illustration. This type includes five different sizes with capacities ranging from 500 lb. to 10,000 lb.

These devices are suited to a wide range of service and find particular application in the small as well as large power plant where rapid and economical lifting and handling of loads is desired. The 500-lb. size has been on the market for a short time but just recently four larger sizes have been added.

Compactness of design, relative light weight, an automatic brake and a graduated throttle which permits close regulation of both the lifting and lowering speeds are the outstanding characteristics claimed for these machines. A balanced three-cylinder air motor is used which operates in either direction and without vibration at any speed or load within the rated capacity of the machine. The motor is of the same type such as has long been provided for Ingersoll-Rand Hoists. It retains all of the best features which have established their worth by long service, and furthermore embodies new features which add to its economy and durability. Some of the advantages of this motor are its freedom from vibration, the ready manner in which it can be throttled down slowly at all loads and its remarkable absence of lubricating troubles, even when subjected to considerable neglect.



INGERSOLL-RAND AIR MOTOR HOIST

It should therefore be noted that these hoists are entirely distinct from direct-acting cylinder hoists and lifts. The latter consist essentially of only the plunger and a case. The Ingersoll-Rand Air Hoists, on the other hand, are equipped with a high powdered and efficient air motor which is geared through a mechanical train to a hoisting drum.

It is claimed that the throttle graduation on the new hoists is extremely fine and this ensures instant and complete control of the hoist at any speed and contributes to the excellent operating performance. A safety stop lever is provided which closes the throttle and stops the motor whenever the load is by chance raised to the top of the hoist lift. The automatic brake is a new feature and it holds the load at any desired position for any length of time regardless of air pressure. The brake consists of a disc attached to the motor shaft, and of a brake plunger with a friction face, which is held in contact with the disc by springs whenever the hoist is not operating, i.e., whenever the air supply to the motor is cut off either by throttling or otherwise. It is entirely automatic in its action and requires no attention from the operator.

Lubrication of all parts has been thoroughly provided for. The motor and gears are both enclosed. The motor operates in a bath of oil and the gears turn in a heavy

grease. Oil passages lead to all bearings. Ball bearings or bronze bushings are provided at all points where experience has indicated they will add to the efficiency or life of the hoist.

If the hoists are overloaded it is only necessary to remove the overload, after which the hoist will start up and operate again.

American Members of St. Lawrence Commission Appointed

IN PURSUANCE of the correspondence with the Canadian Government in respect to advancement of improvement of the St. Lawrence River, President Coolidge has appointed the St. Lawrence Commission of the United States, comprising: Herbert Hoover, Secretary of Commerce, Chairman; Wm. C. Breed, Attorney-at-Law, New York City; James E. Davidson, Bay City, Mich., Vice-President, American Ship Building Co.; James P. Goodrich, Winchester, Ind., formerly Governor of Indiana; James R. Howard, Chicago, Ill., formerly President, American Farm Bureau Federation; James D. Noonan, American Federation of Labor; Stephen B. Davis, Washington, D. C., Counsel, and Charles P. Craig, Duluth, Minn., Executive Secretary.

A further member of the Commission will be chosen from the commercial community in the New England States.

In his letter of instruction to Secretary Hoover President Coolidge expressed his desire that the Commission should thoroughly consider the whole project in its economic and national aspects, should solicit the views of the various sections of the community, should be able to express an opinion as to whether or not the project should be undertaken at the present time. If this judgment should be in the affirmative, then he wishes the Commission to consider the formulation of such projects as might be submitted for international agreement on construction, finance and administration—all of which of course must be of a preliminary nature as a basis for formal negotiations with the Canadian Government, and obviously subject to the views of Congress.

News Notes

THE FIRST ANNUAL MEETING of the American Association of Oil Burner Manufacturers will be held at the Hotel Chase, St. Louis, April 1, 2, and 3, 1924, according to announcements recently made by the Association. A program of speakers of national reputation on both industrial and domestic oil burners has been arranged and the Association has issued a general invitation to firms and individuals in allied industries to attend these meetings. Exhibits of oil burners and oil burning equipment will be shown on the Roof Garden of the Hotel.

JOSEPH W. HAYS announces the establishment of the Hays Institute to facilitate distribution of his original course on fuel and combustion engineering as well as several new courses which are designed for men who do not feel that they can use the longer course to advantage. Administration of the business and educational features of the courses will be under the management of the same men as heretofore.

MANY IMPROVEMENTS, including extension of electric transmission lines, are contemplated for the properties of the new Missouri Power and Light Co., according to a statement by officials of the company. One is a new transmission line in Missouri from Jefferson City, capital of the state, to Auxvasse, connecting with a line already built from there to Mexico. Another line in Missouri, officials said, will be built from Clark, through Moberly to La Plata, to connect with one already between La Plata and Kirksville.

IN ORDER TO PROVIDE for the proper exchange of power between the many generating stations of the Commonwealth Edison Co., an extension is being planned to its switch house at the Fiske St. generating station in Chicago.

KARL A. LEFREN, formerly chief engineer of the Robert Gair Co. has opened a consulting engineering office at 171 Madison Ave., New York City, where he will engage in the practice of engineering in connection with power, paper mills and general mill construction.

MCCLAVE-BROOKS CO., of Scranton, Pa., announces the removal of its Chicago office from the Hearst Bldg. to 501 Chicago Trust Bldg. All correspondence to that office should be addressed to J. C. Sanders, who is manager of the office.

THE CUMBERLAND COUNTY POWER & LIGHT CO., which erected a steam plant at Knightville, Me., about a year ago at a cost of $1,000,000, plans to erect an addition costing approximately $1,500,000 this season. It is proposed to increase the 10,000 kw. capacity of the plant to 22,500 kw.

H. W. JARRETT announces change of office address from 5005 Euclid Ave., Cleveland, O., to the Rockefeller Bldg. The following companies are represented: Hagan Corporation, Pittsburgh; The Williams Gauge Co., Pittsburgh; Bernitz Furnace Appliance Co., Boston; National Company, Boston; Botfield Refractories Co., Philadelphia.

THE KENTUCKY UTILITIES CO. is soon to start operating its new Pineville Plant, the first generating unit of which was recently shipped. Two 15,000-kw. machines were ordered, the second of which is being built for shipment the latter part of this year. The Pineville plant will furnish power for distribution in that vicinity for general purposes. It is expected that its ultimate capacity will be about 200,000 kw.

THE NARRAGANSETT ELECTRIC LIGHTING CO. of Providence, R. I., will instal four new boilers, each of 1850 hp. capacity, for which authority has been granted by the directors to spend $1,000,000. The new boilers will have several times the capacity of the boilers now in use. They will be designed to burn oil, pulverized coal or soft coal and with new labor saving devices, will require no increase in the force handling their operation. The boilers will be ready for operation next fall.

EFFORTS OF MAYOR HALLSTROM and some of the Aldermen of Rockford, Ill., to secure passage of an ordinance for a $150,000 bond issue to build a municipal electric plant have been defeated by a vote of the board of aldermen of that city. In the debate preceding the vote, General Manager Gschwindt of the Rockford Electric Co. gave facts in regard to rates and service of the company which were convincing as to the ability of the company to deliver service more cheaply and effectively than a municipal plant. He stated that it was the policy of the company to make it possible so as to keep the position it has always occupied

—the lowest rates of any city in the state, coal cost considered. The plant has been rebuilt since 1911, only one generator and 3 small boilers remaining of the old plant. Two new turbines have been installed and a third is ordered for delivery soon. High-pressure boilers have replaced the old ones and a new switchboard has been installed.

FERRY C. HOUGHTEN has recently been appointed to the office of Secretary of the American Society of Heating & Ventilating Engineers to succeed C. W. Obert, whose resignation was tendered the society a few weeks ago. Mr. Houghten has been connected with the U. S. Bureau of Mines in Pittsburgh since 1918 and in 1920 he became assistant to Dr. Allen, the director of the society's research laboratory. His appointment is in recognition of successful investigations which he has supervised, dealing with scientific problems such as investigations of human reactions to high temperature and humidities, comfort, zone, critical velocity of steam in pipes, air infiltration in buildings and heat transmissions.

ANNOUNCEMENT has just been made that the John H. McGowan Co., of Cincinnati, Ohio, has purchased the Twinvolute Pump & Mfg. Co., of Newark, N. J., and will manufacture in addition to its water works pumping engines, a complete line of centrifugal pumps consisting of side suction, horizontally split-case, double-suction, single and multi-stage pumps, made in either belt or motor-driven types.

These pumps range in capacities from 5 to 125 gal. per min., with heads up to 70 ft. for the side suction pumps. In the horizontally split-case design, the capacities range from 30 to 2100 gal. per min. for heads up to 230 ft. for single stage, and higher heads in the multi-stage patterns.

In addition to these types, the company will manufacture automatic sump pumps, also pumps and receivers of various sizes. In the design of this new product of the McGowan Co. the uppermost thought has been that of producing efficient pumps that are readily accessible, constructed so that the wearing parts can be readily and inexpensively replaced maintaining efficiency.

ANNOUNCEMENT IS made that the Wheeler Condenser & Engineering Co. has absorbed the Alberger Pump & Condenser Co., thus combining the lines of these two companies in manufacturing condensing equipment, centrifugal pumps and heaters. Pumps will be made at the Alberger Works at Newburgh, N. Y., while the Carteret, N. J., works will be devoted to the manufacture of large condensing equipment.

Catalog Notes

TYPE "V" AIR WASHERS are described in a new catalog No. 71 published by the Clarage Fan Co., of Kalamazoo, Mich. This is a new product and is adaptable for every sort of work where it is necessary or desirable to circulate air which has been washed properly and humidified.

KIELEY AND MUELLER, INC., of New York, has just issued a new catalog of its steam, water and air specialties. This catalog contains complete descriptions of the company's products and is well illustrated. A handy feature of the book is the fact that all articles are shown by picture and described on the same page.

QUIGLEY FURNACE SPECIALTIES CO., of New York, has issued a new booklet on Ganisand and its uses. Ganisand is a highly refractory ganister of uniform grade properly proportioned to form correct aggregates for furnace work. It is bonded with high temperature cement to reconstruct, repair and resurface furnace structures and to make rammed-in linings, special tile and shapes.

"WEBSTER FROM THE AIR" is the name of an attractively illustrated booklet published by Warren Webster and Co., of Camden, N. J. In this booklet are assembled exceptionally fine airplane photographs of 24 American cities. These views, while they have no direct bearing upon Warren Webster Heating Systems, are indicative of representative cities in which these heating systems are used.

THE WATER WORKS PUMPING STATION of the City of Allentown, Pa., is described in an illustrated leaflet issued by the De Laval Steam Turbine Co., of Trenton, N. J. The station as a whole may be considered a good example of a reliable and economical plant for a small city. The water supply for the 85,000 inhabitants is taken from two springs, one located near the pumping station and the other at a distance of 5 mi. and cool, clear and pure water is supplied to 19,000 connections at a single family rate of only $3.75 net per year. The pressure varies from 40 to 100 lb., which is sufficient for fire purposes.

UNUSUAL AND INTERESTING is the impression given by a blueprint booklet gotten out by the Ruggles Klingemann Manufacturing Co. of Boston and Salem, Mass. The booklet is devoted to the applications of temperature and pressure control regulators and shows the different ways in which these devices can be applied to hot water heating systems, hot water tanks of large and small sizes, control of the steam supplied to feed water heaters, pump control, and for the regulation of fans and blowers. Results in steam saving by the use of these regulators are also shown by means of diagrams and charts.

WESTINGHOUSE ELECTRIC and Manufacturing Co. has recently issued a 24-page, two-color, illustrated booklet entitled "Indicating Instruments for Direct and Alternating Currents." The introductory chapter includes a brief resume of the development of electricity with special reference to the development of alternating current and the earlier alternating-current instruments. The remainder of the book is devoted to the instruments themselves. One chapter is devoted to questions of standardization and sizes, insulation, compactness, readability, sturdiness, acessibility, simplicity, damping, accuracy and calibration. Another chapter offers a description in detail of the parts making the completed instrument. The last chapter is devoted to instrument applications.

GIRTANNER STEAM Jet Ash Conveyors are described in a 16-page catalog recently issued by the Girtanner Engineering Corporation, of New York City.

"WING FEATHERWEIGHT UNIT HEATER" is the name of a 4-page bulletin issued by the L. J. Wing Mfg. Co., of New York City. This heater is a small, light weight air heater for general industrial application, employing a heating element of seamless copper tubing. The air passes through the tubes and steam surrounds them, as contrasted with heavy weight iron pipe coils in which the steam passes through the pipes and the air around the outside of the pipes.